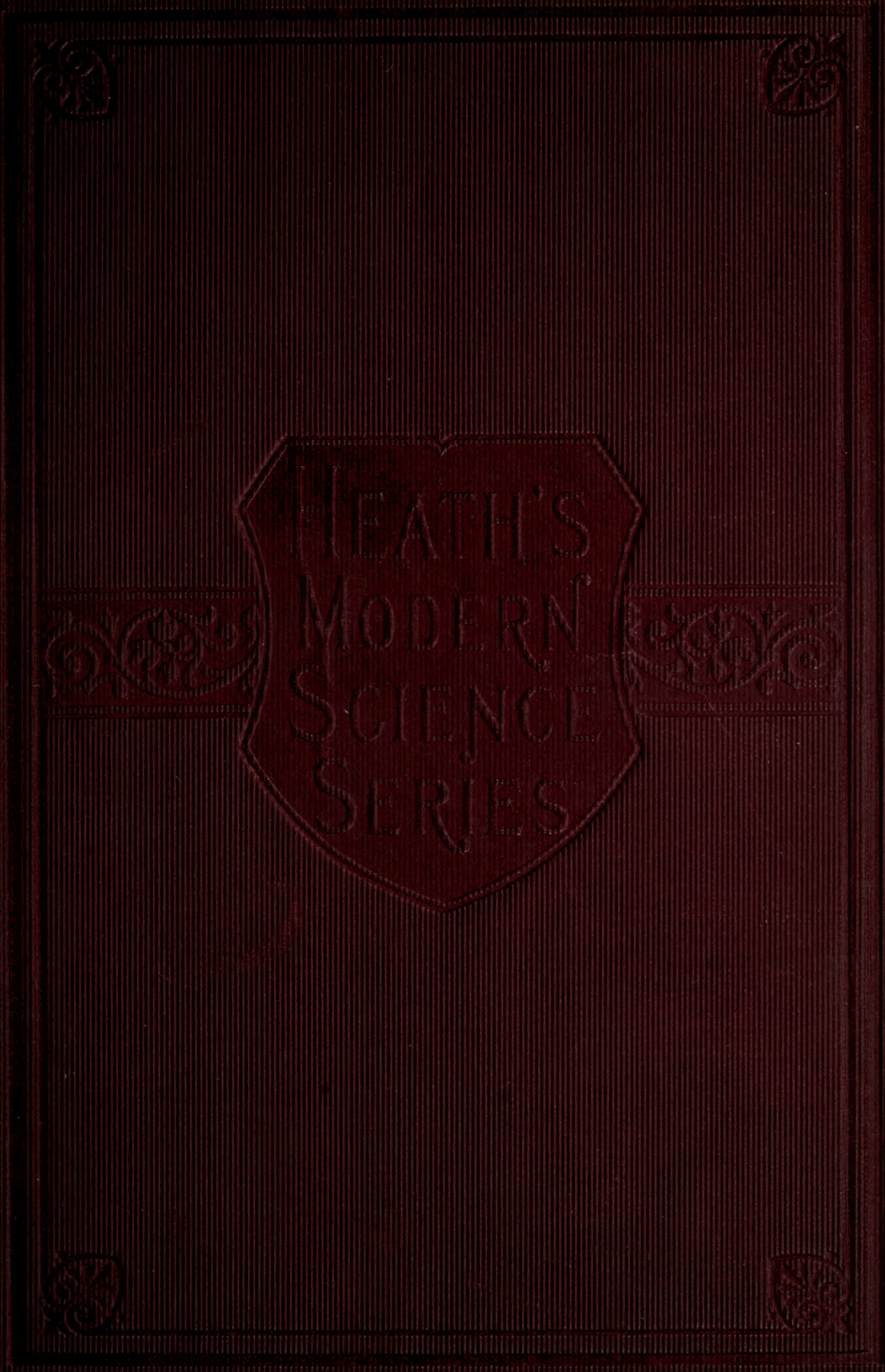

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DESCRIPTIVE CHEMISTRY

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BY

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PART II
EXPERIMENTS

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INTRODUCTION.

1. The Bunsen burner is used as the source of heat in most chemical laboratories (Fig. 87). It is attached to the gas cock by a piece of rubber tubing. When the gas is turned on, the current of gas draws air through the holes at the bottom of the tube, and this mixture when lighted burns with an almost colorless, *i. e.* non-luminous, flame. It is a hot flame and deposits no soot. The burner is lighted by turning on the gas full and holding a lighted match in the gas about 5 centimeters (2 inches) above the top of the burner. If the flame is not colorless, or nearly so, turn the ring at the bottom of the burner until the flame is a faint blue. The colorless flame should be used in all experiments unless the directions state otherwise, and should be from 5 to 10 centimeters (2 to 4 inches) high. The hottest part of the flame is near the top.

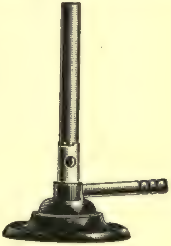

FIG. 87. — Bunsen burner.

2. Heating. — The following directions should be observed in heating with the Bunsen burner: —

(1) The burner should always be lighted before any piece of apparatus is held over it, or before it is placed beneath a wire gauze which supports a dish or flask.

(2) Glass and porcelain apparatus should not be heated when empty nor over a bare or free flame even if they contain something — unless directions so state. Vessels requiring a support should be placed on a wire gauze which stands on the ring of an iron stand, and heated gradually from beneath. Hot vessels should be heated and cooled gradually; if removed from the gauze while hot, they should be placed on a block of wood or piece of asbestos board — never on a cold surface.

(3) Many experiments require the heating of test tubes. These tubes should be dry on the outside before being heated. The temperature of a test tube containing a solid should be raised gradually by moving it in and out of the flame, or by holding it in the flame and roll-

ing it slightly between the thumb and forefinger. Special care must be taken to distribute the heat evenly. If the test tube contains a liquid, as is usually the case, only that part containing the liquid should be heated; the test tube should also be inclined so that the greatest heat is not directed upon the thin bottom. When the liquid begins to boil, the test tube should be removed from the flame for an instant or held over it. In some experiments test tubes can be held between the thumb and forefinger without discomfort. If they are too hot to handle, a test-tube holder may be used (Fig. 88).

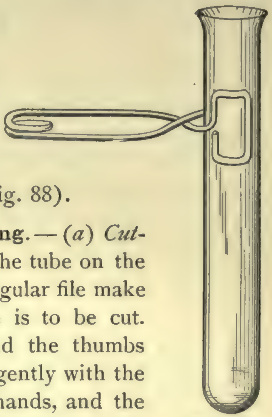

FIG. 88.—Test tube and holder.

3. Cutting and bending Glass Tubing.—(*a*) *Cutting.* Determine the length needed, lay the tube on the desk, and with a forward stroke of a triangular file make a short but deep scratch where the tube is to be cut. Grasp the tube in both hands, and hold the thumbs together behind the scratch. Now push gently with the thumbs, pull at the same time with the hands, and the tube will break at the desired point. The sharp ends should be smoothed by rubbing them with emery paper or by rotating them slowly in the Bunsen flame until a yellow color is distinctly seen or until the ends become red-hot.

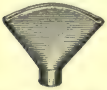

FIG. 89.—Wing-top attachment for Bunsen burner.

(*b*) *Bending.* Glass tubes are bent in a flat flame. An ordinary illuminating gas flame may be used, but the Bunsen flame can be flattened by a wing-top attachment (Fig. 89), which slips over the top of the burner tube. The flattened Bunsen flame should be slightly yellow and about 7 centimeters (2.5 inches) wide for ordinary bends. A **right-angle bend** is made as follows: Determine the point at which the tube is to be bent. Grasp the tube in both hands, and hold it so that the part to be bent is directly over the

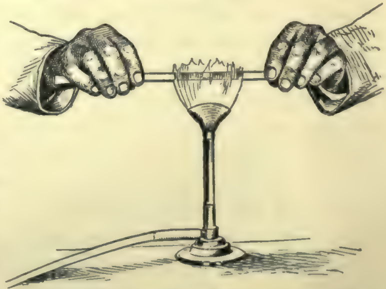

FIG. 90.—Bending a tube into a right angle—I.

flame. Slowly rotate it between the thumbs and forefingers, and gradually lower it into the position shown in Figure 90. Continue to rotate it until the glass feels soft and ready to yield. Then remove it from the flame, and slowly bend it into a right angle, as shown in Figure 91. It is convenient to have at hand a block of wood or some other right-angled object to assist the eye in completing the bend into an exact right angle. If a Bunsen flame is used, the bent part of the tube should be annealed, *i.e.* cooled slowly. This is done by holding it in a yellow flame until it becomes coated with soot. It should then be placed on a block of wood, and when cold wiped clean. Tubes can be **bent into an oblique angle** by heating them through about twice the space required for a right angle; a very slight bend, however, is often made by holding the tube *across* the flame and heating a short space. Glass tubes which have been correctly bent never have flattened curves; nor are they twisted, *i.e.* all parts lie in the same plane.

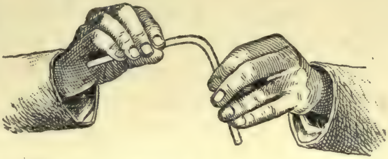

FIG. 91.—Bending a tube into a right angle—II.

(*c*) *Drawing.* Glass tubes can be drawn to a finer bore or into two pointed tubes as follows: Heat the glass as in (*b*) through about 2.5 centimeters (1 inch) of its length, remove from the flame and slowly pull it apart a short distance; let it cool for a few seconds, and then pull it quickly to the desired length.

The operation is well illustrated by making a glass **stirring rod.** Select a piece of rod about 25 centimeters (10 inches) long and .5 centimeter ($\frac{3}{16}$ inch) in diameter. Heat it in the middle in the ordinary — not flat — Bunsen flame, and when soft draw it out slowly into the shape shown in Figure 92. Cut it into two rods by making a slight scratch where the dotted line indicates. Round off the rough edges by heating them slightly in the flame.

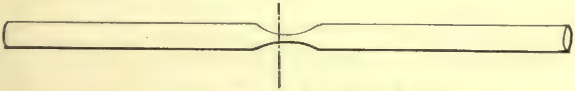

FIG. 92.—Stirring rods ready to be cut.

4. Filtering. — A solid may be separated from a liquid by filtering. A circular piece of porous paper is folded to fit a glass funnel, and when the mixture is poured upon this paper, the solid — the residue or precipitate — is retained, while the liquid — the filtrate — passes through and may be caught in a test tube or any other vessel. The filter paper is prepared for the funnel by folding it successively into the shapes shown in Figures 93 and 94, and then opening the folded paper so that three thicknesses are on one side and one on the other (Fig. 95). The cone-shaped paper is next placed in the funnel and wet with water, so that it will stick to the sides of the funnel and filter rapidly. The paper should never extend above the edges of the funnel, but its apex should always project slightly into the stem. The liquid to be filtered should be poured down a glass rod which touches the edge of the test tube; the lower end of the rod should just touch the paper inside the funnel, so that the liquid will run down the side and thereby avoid bursting the apex of the filter paper. It is also advisable to adjust the apparatus so that the end of the stem of the funnel rests against the side of the vessel catching the filtrate. A funnel can be supported by standing it in a test tube, a bottle, or the ring of an iron stand.

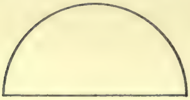

FIG. 93. — Folded filter paper — I.

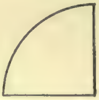

FIG. 94. — Folded filter paper — II.

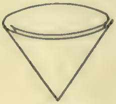

FIG. 95. — Folded filter paper ready for funnel.

5. Constructing and arranging Apparatus. — The various parts of an apparatus should be collected, prepared, and put together before starting the experiment in which the apparatus as a whole is used. The different parts which are to fit each other should be selected and arranged so that all joints are gas-tight, and as a final precaution the apparatus should be tested for leaks. All leaks should be stopped up before the apparatus is used. The following hints will be helpful: —

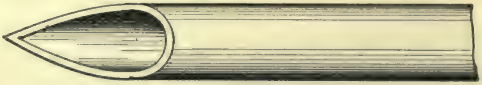

FIG. 96. — Rubber tube cut at an angle.

(1) *To insert a glass tube into rubber tubing.* Cut the rubber tubing at an angle, as shown in Figure 96, moisten the smoothed end of the glass

tube with water, place the end of the glass tube in the angular-shaped cavity so that both tubes are at about a right angle, and then slip the *rubber* tube slowly up and over the end of the glass tube. If the glass tube is large or the rubber stiff, the rubber tube must be held firmly between the thumb and forefinger to keep it from slipping off until it is securely adjusted.

(2) *To fit a glass tube to a stopper.* Moisten the end with water and grasp the tube firmly about 3 centimeters (1 inch) from the end; hold the stopper between the thumb and forefinger of the other hand, and work the tube into the hole by a gradual rotary motion. Proceed in the same manner if the tube is to be pushed through the stopper. *Never* point the tube toward the palm of the hand which holds the stopper. *Never* grasp a safety tube or any bent tube at the bend when inserting it into a stopper — it may break and cut the hand severely.

(3) *To bore a hole in a cork.* Rubber stoppers are preferable, but if corks are used, they can be bored as follows: Select a cork free from cracks or channels and use a borer which is one size smaller than the desired hole. Hold the cork between the thumb and forefinger, press the larger end against a firm but soft board, and slowly push the borer by a rotary movement through the cork, taking care to keep the borer perpendicular to the cork. If the hole is too small, enlarge it with a round file. If corks are used instead of rubber stoppers, the apparatus should always be tested before use by blowing into it, stopping of course all legitimate outlets. A poor cork often means a failure, to say nothing of wasted time.

(4) *To make a platinum test wire.* Rotate one end of a piece of glass rod, about 10 centimeters (4 inches) long, in the flame until it softens. At the same time grasp a piece of platinum wire about 7 centimeters (3 inches) long firmly in the forceps about 1 centimeter (.5 inch) from the end, and hold it in the flame. When the rod is soft enough, gently push the hot wire into the rod. Cool the rod gradually by rotating it in the flame. The completed wire is shown in Figure 97. If a glass tube is used instead of a rod, it should be drawn out to a very small diameter (see § 3 (*c*)) before inserting the platinum wire, but in other respects the two operations are practically identical.

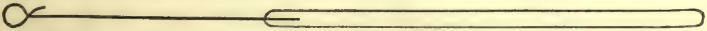

FIG. 97. — Platinum test wire.

6. Manipulation. — Ability to use apparatus rapidly, accurately, and neatly is acquired only by experience, but the following suggestions will facilitate the acquisition of this needful skill: —

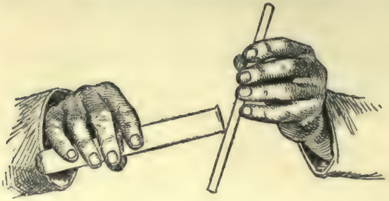

FIG. 98. — Pouring a liquid down a glass rod.

(1) *Pouring liquids and transferring solids.* (*a*) Liquids can be poured from a vessel without spilling, by moistening a glass rod with the liquid and then pouring it down the rod as is shown in Figure 98. The angle at which the rod is held varies with circumstances. This is a convenient way to pour a liquid from a vessel containing a solid without disturbing the solid. (*b*) Liquids can often be poured from a bottle by holding the bottle as shown in Figure 99. Notice that the stopper and bottle are held in the same hand. This is accomplished by holding the palm of the hand upward and removing the stopper by grasping it between the fingers before the bottle is lifted. All stoppers should be removed this way when possible, and not laid down, because the impurities adhering to the stopper may run down into the bottle and contaminate the solution. The drop on the lip of the bottle should be touched with the stopper before the latter is put into the bottle; this simple operation prevents the drop from running down the outside of the bottle upon the label or upon the shelf. (*c*) Solids should never be poured directly from a large bottle into a test tube, retort, or similar vessel. A convenient method is as follows: Rotate the bottle slowly so that the

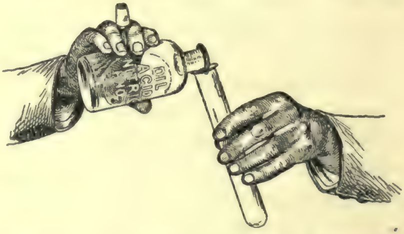

FIG. 99. — The way in which a glass stopper should be held while a liquid is being poured from a bottle.

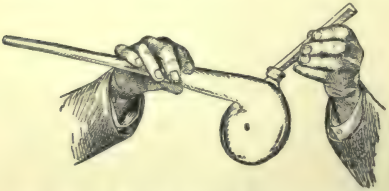

FIG. 100. — Pouring a solid into a vessel with a small opening.

solid will roll out in small quantities; catch the solid on a narrow strip of paper folded lengthwise, and slide the solid from the paper into the desired vessel. The last part of the operation is shown in Figure 100.

(2) *Collecting gases.* Gases are usually collected over water by means of a pneumatic trough, a common form of which is shown in Figure 102. The vessel to be filled with gas is first filled with water, covered with a piece of filter paper, inverted, and placed mouth downward on the shelf of the trough, which is previously filled with water just above the shelf. The paper is then removed, and the vessel slipped over the hole in the shelf of the trough. Glass plates instead of filter paper may be used to cover the bottle. The gas which is evolved in the generator passes through the delivery tube, and bubbles up through the water into the bottle, forcing the water out of the bottle as it rises. All gases insoluble in water are thus collected. Some heavy gases, such as hydrochloric acid, chlorine, and sulphur dioxide, are collected by allowing the gas to flow downward into an empty bottle, and displace the air in the bottle, *i.e.* by *downward displacement.* Ammonia and other light gases are usually collected by allowing the gas to flow upward into a bottle, *i.e.* by *upward displacement.*

(3) *Weighing and measuring.* These operations are best learned by personal direction from the teacher, together with patient application of a few general principles. The following hints, however, will be of assistance: —

(*a*) Learn as soon as possible how to use the scales and interpret the weights.

(*b*) Always leave the scales and weights in a clean, usable condition.

(*c*) Substances should not be weighed on the bare scale pan, but on a smooth piece of paper creased on the edges or along the middle. Take the solid from the bottle with a *clean* spoon or spatula or pour by rotating the bottle as described in § 6 (*c*). In many experiments only approximate quantities are needed. If you weigh out too much, do not put it back into the bottle, but throw it away or put it into a special bottle.

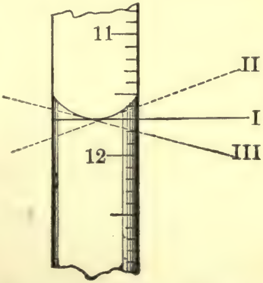

FIG. 101. — Meniscus. Correct reading is along line I.

(*d*) Liquids are measured in graduated cylinders. The lowest point of the curved surface of the liquid is its correct height (see Fig. 101). The average ordinary test tube holds about 30 cubic centimeters, while the large test tube — so often mentioned in the succeeding experiments — holds about 75 cubic centimeters. Time can be saved by remembering these volumes.

(*e*) All measurements in this book are in the metric system (see App. § 1). The common denominations, their abbreviations, and English equivalents should be learned.

7. Smelling and Tasting. — Unfamiliar substances should never be tasted or smelled except according to directions, and even then with the utmost caution. Never inhale a gas vigorously, but waft it gently with the hand toward the nose. Taste acids, etc., by touching a minute portion to the tip of the tongue, and as soon as the sensation is detected, reject the solution at once — never swallow it.

EXPERIMENTS.

PHYSICAL AND CHEMICAL CHANGES.

Experiment 1. — Physical Change. *Materials:* Salt, glass rod.

Dissolve a little salt in a test tube one fourth full of water. Dip a glass rod into the liquid and taste it. Has the characteristic property of the salt been changed? Dip the rod into the liquid again, and hold it *over* the flame of the Bunsen burner. As the water evaporates, a white solid appears. Taste it. What is it? Have its original properties been destroyed? What kind of a change did they undergo? What kind of a change did the salt undergo? What caused the change?

Experiment 2. — Physical Change. *Material:* Iodine.

Drop a small crystal of iodine into a dry test tube, and gently heat the bottom. As the violet vapor arises, remove the tube from the flame and let it cool. Do the crystals which form near the top resemble the original crystal? When gently heated, do they change into the violet vapor? How has the iodine crystal been changed? What caused the change? Do the original properties reappear after the cause has been removed? What kind of a change has the iodine undergone?

Experiment 3. — Physical Change. *Material:* Glass rod.

Rub a glass rod briskly on a piece of cloth, and hold it near small bits of dry paper. Describe what happens. After a moment touch the paper again. Is the result the same? Try again. Are the original properties of the glass restored when the cause of its change is removed? What kind of a change did the glass undergo?

Experiment 4. — Chemical Change. *Materials:* Copper wire, dilute nitric acid, iron nail, forceps.

(*a*) Examine a piece of copper wire and notice especially its color. Grasp one end of the wire with the forceps, and hold the other end in the flame until a definite change occurs. Then remove it from the flame, and examine. Has it been changed? Do the original properties of the copper reappear when the heated wire is cool? What kind of a change has the copper undergone? Has the change produced another substance?

(*b*) Slip another piece of copper wire into a test tube one fourth full of dilute nitric acid. Notice any change. Warm the liquid gently, and notice any additional change. What are the evidences of chemical change? What caused the change? What assisted or hastened it? How has the copper been changed? (Save the test tube and contents for (*c*).)

(*c*) Carefully slip an iron nail into the liquid remaining from (*b*); let it stand a short time. Then remove and examine the coating. How does it compare with the original copper used in (*a*)? What kind of a change occurred? What caused it?

ANSWER:

(1) What are the evidences of chemical changes in this experiment?

(2) If a known weight of copper had been consumed in (*b*), could it have been obtained without loss in (*c*)?

(3) Did the changes in this experiment involve any loss of copper?

(4) What is the evidence that new substances were produced in (*a*) and (*b*)?

(5) What physical changes occurred in (*a*) and (*b*)?

OXYGEN.

Experiment 5. — Preparation of Oxygen. *Materials:* 15 grams potassium chlorate, 15 grams manganese dioxide, 5 bottles (about 250 cubic centimeters each), filter paper, thin piece of soft wood, sulphur, deflagrating spoon, piece of charcoal fastened to a wire, piece (about 15 centimeters or 6 inches) of wire picture cord unwound at one end. The *apparatus* is shown in Figure 102. *A* is a large test tube provided with a one-hole rubber stopper, to which is fitted a short glass tube, *B*; the delivery tube, *D*, is attached to the short glass tube by the rubber tube, *C*. (Directions for constructing and arranging the apparatus may be found in the Introduction, § 5.)

Weigh the potassium chlorate on a piece of paper creased lengthwise, and slip it into the test tube; do the same with the manganese dioxide. Shake the test tube until the chemicals are thoroughly mixed; then hold the test tube in a horizontal position and roll or shake it until the mixture is spread along the tube its entire length. Insert the stopper with its tubes, and clamp the test tube to the iron stand, as shown in the figure, taking care not to crush the tube; the test tube should incline toward the trough, to prevent any water from flowing back upon the hot glass.

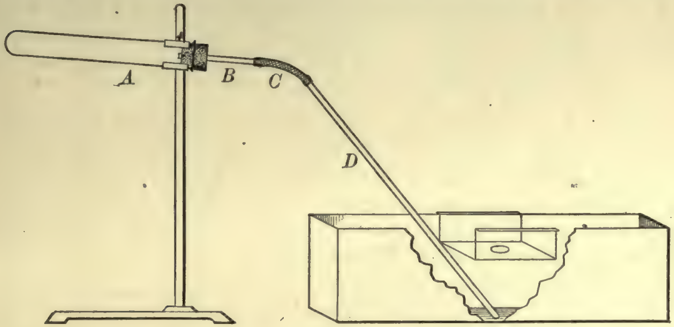

FIG. 102. — Apparatus arranged for preparing oxygen.

Fill the pneumatic trough with water until the shelf is just covered. Fill the bottles *full* of water, cover each with a piece of filter paper, invert them in the trough, and remove the filter paper; leave two bottles on the shelf and three on the bottom. The end of the delivery tube should rest on the bottom of the trough, just under the hole in the shelf.

Heat the whole test tube gently with a flame about 8 centimeters (or 3 inches) high. When the gas bubbles regularly through the water, slip a bottle over the hole. The gas will rise in the bottle and force out the water. Move the flame slowly along the test tube, but concentrate the heat toward the closed end, and always keep the flame behind any water which may be driven out of the mixture. If the gas is evolved too rapidly, lessen the heat; if too slowly, increase it; if not at all, examine the stopper and the rubber connecting tube for leaks, and adjust accordingly. When the first bottle of gas is full, remove and cover it with a piece of wet filter paper, and slip another bottle over the hole. When five bottles of gas have been collected, remove the end of the delivery tube from the water, lest the cold water be drawn up into the hot test tube as the gas contracts.

Perform the next experiment at once.

Experiment 6. — Properties of Oxygen.

Proceed as follows with the oxygen prepared in the preceding experiment.

(*a*) Dip a glowing stick of wood into one bottle, and observe the change. Remove the stick, and repeat as many times as possible. Does the gas burn? How does the glowing stick change? What property of oxygen does this experiment show?

(*b*) Put a small piece of sulphur in the deflagrating spoon, hold the spoon in the flame until the blue flame of the burning sulphur can be seen, then lower the spoon into a bottle of oxygen. Notice the change in the flame. Describe it. Brush a little of the vapor *cautiously* toward the nose. Of what does the odor remind you? (Plunge the spoon into water to extinguish the burning sulphur, and cover the bottle with a piece of filter paper.)

(*c*) Hold the charcoal in the flame long enough to produce a faint glow, then lower it into a bottle of oxygen. Describe the result.

(*a*) Melt the sulphur in the deflagrating spoon, and dip the unwound end of the wire picture cord into the melted sulphur. Lower the end coated with burning sulphur into a bottle of oxygen. The iron wire should burn brilliantly. Describe the change. Sometimes the substance produced by the change coats the inside of the bottle Describe it, if it is visible.

(*e*) With the remaining bottle, repeat any of the above experiments.

EXERCISES:

(1) Write a brief account of the above experiments in your note book, answering all questions and directions.

(2) Sketch the apparatus used to prepare oxygen.

(3) Summarize the properties of oxygen.

(4) What is its most characteristic property?

(NOTE. — The test tube used in Experiment 5 may be cleaned with warm water.)

Experiment 7. — Preparation of Oxygen from Mercuric Oxide.

Materials: Mercuric oxide, stick of wood.

Put a little mercuric oxide on the end of a narrow piece of paper creased lengthwise, and slip the powder into a test tube. The powder should nearly fill the round end of the test tube. Hold the test tube in a horizontal position, shake it to spread the powder into a thin layer, attach the test-tube holder, and heat the test tube (still horizontal) in the upper part of the Bunsen flame. Do not heat one place, but move the tube back and forth. As soon as a definite change is noticed inside the tube, insert a glowing stick of wood. Observe and describe the change. If there is no change, heat strongly, and test again. What gas is liberated? Observe the deposit inside the tube. What is it? If its nature is doubtful, let the tube cool, and examine again.

EXERCISES:

(1) Describe briefly the whole experiment.

(2) What historical interest has this experiment?

(NOTE. — If the test tube has been partially melted, save it for a subsequent experiment.)

HYDROGEN.

Experiment 8. — Preparation of Hydrogen. *Materials:* Granulated zinc, dilute sulphuric acid, pneumatic trough, four bottles, filter paper, taper, matches. The *apparatus* is shown in Figure 103. *A* is a large test tube provided with a two-hole stopper, through which passes the safety tube, *B*, and the right-angle bend, *C*; the long (15 cm. or 6 in.) delivery tube, *E*, is attached to the bent tube by the rubber tube, *D*.

Precaution. *Keep all flames away from the hydrogen generator.*

Fill the test tube half full of granulated zinc as follows: Crease a piece of paper lengthwise, pour the zinc from the bottle upon the paper, incline the test tube, and slip the zinc into it from the paper — do not drop it in. Insert the stopper with its tubes; if the end of the safety tube does not go in easily, hold the test tube in a horizontal position and shake the zinc about, and at the same time push the stopper gently but firmly into place. Clamp the apparatus into the position shown in the figure or stand it in a test-tube rack. Fill the pneumatic trough with water as before, and adjust the apparatus so that the end of the delivery tube rests on the bottom of the trough under the hole in the shelf.

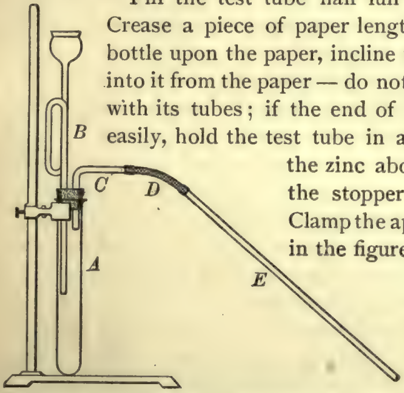

FIG. 103. — Apparatus for preparing hydrogen.

Fill the bottles with water and invert them in the trough, as in Experiment 5.

Pour enough dilute sulphuric acid through the safety tube to fill the test tube about half full, taking care to leave a little acid in the lower bend of the safety tube. This precaution prevents the gas from escaping from the back of the apparatus; if at any time the gas should flow backward, pour a little acid into the bend; if the acid does not flow down the safety tube, loosen the stopper for an instant. As soon as the interaction of the zinc and sulphuric acid produces hydrogen, the gas will bubble freely through the water in the trough. Slip a bottle over the hole, and collect and remove the bottle of gas as in Experiment 5, taking care to cover the bottle firmly with a piece of wet filter paper. If the evolution of gas slackens or ceases, add a little more acid through the safety tube. Collect four bottles of hydrogen, and proceed at once with the next experiment.

Experiment 9. — Properties of Hydrogen.

Study as follows the hydrogen gas prepared above: —

(*a*) Uncover a bottle for an instant to let a little air in, and then drop a lighted match into the bottle. Describe the result.

(*b*) Remove the paper from a bottle of hydrogen, and allow it to remain uncovered for three minutes — by the clock. Then show the presence or absence of hydrogen by dropping a lighted match into the bottle. Describe the result. What property of hydrogen is shown by this experiment?

(*c*) Verify your answer to the last question, thus: Hold a bottle of air over a covered bottle of hydrogen, remove the paper, and bring the mouths of the bottles close together. (See Fig. 1.) Hold them there for a minute or two, then stand the bottles on the desk and cover them with wet filter paper. Drop a lighted match into each bottle. What has become of the hydrogen? How does (*c*) verify (*b*)?

(*d*) Invert a covered bottle of hydrogen, remove the paper, and quickly thrust a lighted taper up into the bottle. Withdraw the taper and then insert it again. Does the hydrogen burn? If so, where? Does the taper burn when in the bottle? When out of the bottle? Feel of the neck of the bottle; describe and explain. What *three* properties of hydrogen are shown by this experiment?

Experiment 10. — Burning Hydrogen. (Teacher's Experiment.) *Materials:* Apparatus shown in Figure 2, which consists of a

500 cubic centimeter flask fitted with a two-hole rubber stopper, safety tube, and double right-angle bend; the last is attached to a U-tube, which is also connected to a delivery tube provided with a short piece of capillary glass tubing; calcium chloride, small bottle, platinum wire, cotton, granulated zinc, dilute sulphuric acid.

Fill the U-tube two thirds full of calcium chloride, put a wad of cotton beneath the stopper of each arm, and connect the U-tube with the generator and the delivery tube.

Stand the apparatus on the table, examine all joints to be sure they are tight, extinguish all flames in the vicinity, and proceed exactly according to the following directions: —

Pour slowly but continuously through the safety tube enough (about 50 cubic centimeters) dilute sulphuric acid upon at least 25 grams of granulated zinc to produce a steady current of hydrogen gas for about five minutes. It is advisable to use considerable zinc and a moderate amount of acid. Acid must not be added after the evolution of gas begins, unless, of course, the experiment is begun anew. Let the gas bubble through the acid for at least *two minutes* by actual observation, then attach the capillary tube by the rubber connector to the end of the delivery tube, leaving a short space between the ends of the two glass tubes so that the rubber tube may be compressed suddenly, if necessary. Let the gas run for *another full minute*. This latter precaution is to drive all air out of the capillary tube. Light the hydrogen, and observe *at once* the nature of the flame, its color, heat (by holding a match or platinum wire over it), and any other striking property. Then hold a small dry bottle over the flame in such a position that the flame is just inside the bottle. When conclusive evidence of the product of burning hydrogen is seen inside the bottle, remove the bottle, and extinguish the flame *at once* by pinching the rubber connector. Remove the generator to the hood, and if the evolution of hydrogen is still brisk, dilute the acid by pouring water through the safety tube. Examine the inside of the bottle. What is the deposit? Explain its formation.

EXERCISES FOR THE CLASS:

(1) What does this experiment suggest about the composition of water?

(2) Does this experiment illustrate oxidation? Why? Synthesis? Why?

(3) Describe the whole experiment, and sketch the apparatus.

WATER.

Experiment 11. — General Distribution of Water. *Materials:* Wood, meat, potato.

Heat successively in dry test tubes a small piece of wood, of meat, or of potato (or any other fresh vegetable). Hold the open end of the test tube lower than the other end. Is there conclusive evidence of water? Since most animal and vegetable substances act similarly, what general conclusion can be drawn from this experiment?

Experiment 12. — Simple Tests for Impurities in Water. *Materials:* Distilled water, water containing dirt, a sulphate, a chloride, and a lime compound; nitric acid, ammonium hydroxide, acetic acid, sulphuric acid (concentrated), solutions of potassium permanganate, silver nitrate, barium chloride, ammonium oxalate; and limewater.

(*a*) *Organic Matter.* Fill a clean test tube half full of distilled water, and another with water containing a little dirt or a bit of paper. Add to each test tube a drop or two of concentrated sulphuric acid and sufficient potassium permanganate solution (made from distilled water) to color each liquid a light purple, as nearly alike as possible. Label one tube, and then heat gently nearly to the boiling point the tube containing the impure water. As soon as a definite change is seen, heat the other cautiously, as too sudden heat may cause the liquid to "bump out." Organic matter decolorizes potassium permanganate solution. Which tube shows the more organic matter?

(*b*) *Chlorides.* To a test tube half full of distilled water add a few drops of nitric acid, and then a few drops of silver nitrate solution. Do the same with water known to contain a chloride in solution. What is the difference between the results? The cloudiness, or solid, is due to silver chloride, which is always formed when silver nitrate is added to hydrochloric acid or a chloride in solution (chlorides being closely related to hydrochloric acid). Silver chloride is soluble in ammonium hydroxide. Try it. This is the usual test for chlorides (and conversely for soluble silver compounds), and will hereafter be used without further description.

(*c*) *Sulphates.* To a test tube half full of distilled water add a few drops of sulphuric acid and a few drops of barium chloride solution. The white precipitate is barium sulphate. It is insoluble in all common liquids, and is always formed when barium chloride is added to sulphuric acid or a sulphate in solution (sulphates being closely related to sulphuric acid). Test the impure water for sulphates.

(*d*) *Lime Compounds.* Add a few drops of a fresh solution of ammonium oxalate to a test tube half full of clear limewater. Limewater is a solution of calcium hydroxide, and the white precipitate formed is calcium oxalate, which is soluble in hydrochloric acid but not in acetic acid. Try it. This is the test for calcium compounds, often called "lime" compounds, because lime, which is calcium oxide, is so well known. Apply this test to distilled water and to water known to contain calcium compounds, and compare the two results.

(*e*) Summarize briefly the whole experiment.

(NOTE. — If time permits, this experiment should be applied by the class to water whose impurities are unknown.)

Experiment 13. — Distillation. (Teacher's Experiment.) *Materials:* Condenser, etc., shown in Figure 6, potassium permanganate, impure water, and solutions used in Experiment 12.

Fill the flask, *C*, half full of water known to contain the impurities mentioned in Experiment 12, add a few crystals (3 or 4) of potassium permanganate, and connect with the condenser as shown in Figure 6. Attach the inlet tube to the faucet, fill the condenser slowly, and regulate the current so that a small stream flows continuously from the outlet tube into the sink or waste pipe. Heat the liquid in *C* gradually, and when it boils, regulate the heat so that the boiling is not too violent. As the distillate collects in the receiver, *D*, test separate portions for organic matter, chlorides, sulphates, and calcium compounds.

EXERCISES FOR THE CLASS:

(1) Is organic matter found?

(2) Is mineral matter found?

(3) If the distilling liquid had contained a volatile substance, like ammonia or alcohol, would the distillate contain such a substance?

Experiment 14. — Solubility of Gases.

(*a*) Warm a little faucet water in a test tube. Is there *immediate* evidence of a previously dissolved gas? Is there evidence of much gas? What effect has increased heat?

(*b*) Warm slightly a few cubic centimeters of ammonium hydroxide in a test tube. Do the results resemble those in (*a*)? As soon as the final result is obtained, pour the remaining liquid down the sink and flush well with water.

(*c*) Repeat (*b*), using a little concentrated hydrochloric acid. Do the results resemble those of (*a*) and (*b*)?

ANSWER:

(1) How does increased temperature affect the solubility of gases?
(2) What gases dissolve freely in water?

Experiment 15. — Solubility of Liquids. *Materials:* Alcohol, kerosene, glycerine, carbon disulphide.

(*a*) To a test tube half full of water add a little alcohol and shake. Is there evidence of solution? Add a little more and shake. Add a third portion. Is there still evidence of solution? Draw a conclusion as to the solubility of alcohol in water.

(*b*) Repeat (*a*), using successively kerosene, glycerine, and carbon disulphide. Observe the results and conclude accordingly.

(*c*) Summarize the results in a table.

Experiment 16. — Solubility of Solids. *Materials:* About 20 grams of powdered copper sulphate, 6 grams of powdered potassium chlorate, 1 gram of calcium sulphate.

(*a*) Label three test tubes I, II, III. Fill each about one third full. To I add 1 gram of powdered copper sulphate, to II add 1 gram of powdered potassium chlorate, to III add 1 gram of calcium sulphate. Shake each test tube, and then allow them to stand undisturbed for a few minutes. Is there evidence of solubility in each case? Is there evidence of a varying degree of solubility? If III is doubtful, carefully transfer a portion of the *clear* liquid to an evaporating dish by pouring it down a glass rod (see Introduction, § 6 (1) (*a*)), and evaporate to dryness. Is there now conclusive evidence of solution? Draw a general conclusion from this experiment. Save solutions I and II for (*b*).

Tabulate the results of (*a*) as follows, using the customary terms to express the degree of solubility: —

TABLE OF SOLUBILITY OF TYPICAL SOLIDS.

SOLUTE.	SOLVENT.	RESULTS.
1. Copper sulphate	Water at temperature of laboratory.	1.
2. Potassium chlorate		2.
3. Calcium sulphate		3.

(*b*) Heat I and add gradually 4 more grams of powdered copper sulphate. Does it all dissolve? Heat II and add 4 more grams of powdered potassium chlorate. Does it all, or most all, dissolve? What general effect has increased heat on the solubility of solids? What is the difference between this general result and that in Experiment 14? Save the solutions for (*c*).

(*c*) Heat I and II nearly to boiling, and as the temperature increases add the respective solids. Do not boil the liquid away. Is there a limit to their solubility? Draw a general conclusion from these typical results.

Experiment 17. — Supersaturation. *Material:* Sodium thiosulphate.

Fill a test tube nearly full of crystallized sodium thiosulphate and add a very little water. Warm slowly. As solution occurs, heat gradually to boiling. Add sodium thiosulphate until no more will dissolve. Pour the solution into a warm, clean, dry test tube and let it stand until cool. Then drop in a small crystal of sodium thiosulphate and watch for any simple but definite change. What happens? Is the excess of solid large? How does a supersaturated solution differ from a saturated one?

Experiment 18. — Water of Crystallization. *Materials:* Crystallized sodium carbonate, gypsum, copper sulphate, evaporating dish, gauze-covered ring (or tripod).

(*a*) Heat a few small crystals of sodium carbonate in a dry test tube, inclining the test tube so that the open end is the lower. What is the evidence that they contained water of crystallization? If there is any marked change in the appearance of the crystals, describe and explain it.

(*b*) Repeat, using a crystal of gypsum. Answer the question asked in (*a*).

(*c*) Heat two or three small crystals of copper sulphate in an evaporating dish which stands on a gauze-covered ring. As the action proceeds, hold a dry funnel or glass plate over the dish. Is there conclusive evidence of escaping water of crystallization? Do the crystals change in color? In shape? Can the form of the crystals be changed by gently touching the mass with a glass rod? Continue to heat until the resulting mass is a bluish gray. Let the dish cool. Meanwhile heat a test tube one half full of water. When the dish has cooled somewhat, pour the hot water slowly into the dish upon the copper sulphate. Explain the change in color, if any. If there are any lumps, crush them with a glass rod. Let the clear solution evaporate for several hours. Are crystals deposited? If not, heat a few minutes, and cool again. If so, why? Have they water of crystallization, and, if so, where did they get it?

Experiment 19. — Efflorescence.

Put a fresh crystal of sodium carbonate and of sodium sulphate on a piece of filter paper, and leave them exposed to the air for an hour or more. Describe any marked change. What does this change show about the air? About the crystal?

Experiment 20. — Deliquescence.

Put on a glass plate or block of wood a small piece of granulated calcium chloride and of sodium hydroxide. Leave them exposed to the air for an hour or more. Describe any marked change which takes place. Compare the action with that of Experiment 19.

Experiment 21. — Solution and Chemical Action. *Materials:* Powdered tartaric acid, sodium bicarbonate, lead nitrate, potassium dichromate, mortar, dish of water.

(*a*) Mix in a dry mortar small but equal amounts of powdered tartaric acid and sodium bicarbonate. Is there any decided evidence of chemical action? Pour the mixture into a dish of water. Is there conclusive evidence of chemical action?

(*b*) Repeat, using powdered lead nitrate and powdered potassium dichromate.

Describe the results in (*a*) and (*b*). How does solution influence chemical action? Why are so many solutions used in the laboratory?

Experiment 22. — Electrolysis of Water. (Teacher's Experiment.) *Materials:* Hofmann apparatus, sulphuric acid, taper, matches, short piece of capillary glass tubing.

Fill the Hofmann apparatus, Figure 10, with water containing 10 per cent of sulphuric acid, so that the water in the reservoir tube stands a short distance above the gas tubes after the stopcock in each has been closed. Connect the platinum terminal wires with a battery of at least two cells. As the action proceeds, small bubbles of gas rise and collect at the top of each tube. Allow the current to operate until the smaller volume of gas is from 8 to 10 centimeters in height. Measure the height of each gas column. Assuming that the tubes have the same diameter, the volumes are in approximately the same ratio as their heights. How do the volumes compare ?

Test the gases as follows: (*a*) Hold a glowing taper over the tube containing the smaller quantity of gas, cautiously open the stopcock to allow the water (or air) to run out of the glass tip, and then let out a little gas upon the glowing taper. What is the gas ? Repeat until the gas is exhausted. Care must be taken not to lose the gas. It is advisable to have at hand several partially burned tapers or thin splints, in case any escaping water extinguishes the first one. (*b*) Open the other stopcock long enough to force out the water in the glass tip; close the stopcock, and, by means of a short rubber tube, attach the capillary tube close to the end of the glass tip. Open the stopcock again, let out the gas slowly, and hold at the same time a lighted match at the end of the tip, then immediately thrust a taper into the small and almost colorless flame. What is the gas ? Repeat until the gas is exhausted.

EXERCISES FOR THE CLASS:

(1) Describe the whole experiment.

(2) Draw a general conclusion from this experiment.

(3) What does this experiment show about the composition of water ?

(4) Sketch the apparatus.

Experiment 23. — Interaction of Water and Chlorine. (Teacher's Experiment.) *Materials:* Glass tube 1 meter long and about 2 centimeters in diameter, cork for one end, evaporating dish, chlorine water.

Construct a chlorine generator, as described in Experiment 38, and prepare about 250 cubic centimeters of chlorine water by causing the gas to bubble through a bottle of water until the water smells strongly of the gas. Close one end of the tube with a cork. The cork must fit air tight, and as a precaution should be smeared (after insertion) with vaseline or coated with paraffin. Fill the tube full of chlorine water, cover the open end with the thumb or finger, invert the tube, and immerse the open end in the evaporating dish, which should be nearly full of chlorine water. Clamp the tube in an upright position, and stand the whole apparatus where it will receive the direct sunlight for at least six hours. Bubbles of gas will soon appear, rise, and collect at the top. When sufficient gas for a test has collected, unclamp the tube, cover the open end with the thumb or finger, invert the tube, and put a glowing taper into the gas. Repeat as long as any of the gas remains.

EXERCISES FOR THE CLASS:

(1) What gas is produced by the interaction of chlorine and water?
(2) Describe this experiment.
(3) What does it show about the composition of water?
(4) Sketch the apparatus.

Experiment 24. — Interaction of Water and Sodium. *Materials:* Sodium, pneumatic trough filled with water as usual, tea lead, forceps, red litmus paper.

Precaution. *Sodium should be handled cautiously and used strictly according to directions. Small fragments must not be left about nor thrown into the refuse jar, but into a large vessel of water especially provided for that purpose.*

(*a*) If the sodium is brown, scrape off the coating. Cut off a piece of sodium not larger than a small pea, and drop it upon the water in the trough. Stand far enough away so that you can just see the action. Wait until you are sure the action has stopped, and then describe all you have seen.

(*b*) The action in (*a*) may be further studied as follows: Fill a test tube with water, invert it, and clamp it in the trough so that the mouth is over the hole in the shelf of the trough. Wrap a small piece of sodium *loosely* in a piece of tea lead about 5 centimeters (2 inches) square, make two or three small holes in the tea lead, and then thrust it under the shelf of the trough with the forceps. A gas will rise into the test tube. Proceed similarly with additional small pieces of sodium and *dry* tea lead until the test tube is nearly full of gas; then unclamp and remove, still keeping the tube inverted. Hold a lighted match, for an instant, at the mouth of the tube. Observe the result, watching especially the mouth of the tube. What is the gas? Why? Remembering that sodium is an element, where must the gas have come from? If there is any doubt about the nature of the gas, collect more, and subject it to those tests which will prove its nature.

(*c*) Put a piece of filter paper on the water in the trough, and before it sinks drop a small piece of sodium upon it. Stand back and observe the result. Wait for the slight explosion which usually occurs soon after the action stops. Describe all you have seen. What burned? What caused it to burn? To what is the vivid color probably due? (In answering these questions, utilize your knowledge (1) of the properties of the gases previously studied, and (2) of the usual accompaniment of chemical action, suggested here by the melting of the sodium.)

(*d*) Test the water in the trough with red litmus paper. Push the paper to the bottom or to the place where it is certain that chemical action between water and sodium has taken place. Test until the red litmus paper has undergone a decided change in color. Describe this final result. With another piece of red litmus paper test a solution of sodium hydroxide. Is the result similar? Dip a glass rod or the platinum test wire (see Int. § 5 (4)) into this solution and hold it in the Bunsen flame. Describe the result. Is the color of this flame and that noticed in (*c*) the same? Are the dissolved substances identical?

(*e*) What does the whole experiment show about the composition of water?

THE AIR.

Experiment 25. — Composition of the Air. *Materials:* Solutions of pyrogallic acid and potassium hydroxide,[1] pneumatic trough half filled with water at the temperature of the room, 500 and 25 cubic centimeter graduated cylinders. The *apparatus* consists of an Erlenmeyer flask (250 cubic centimeters) provided with a one-hole rubber stopper into (but not through) which passes a short glass tube; to the outer end of this tube, which projects 2.5 centimeters (1 inch) above the stopper, a rubber tube (5 centimeters or 2 inches long) is tightly fastened; a Hofmann screw is attached to the rubber tube close to the end of the glass tube.

(*a*) The volume of the flask is found thus: Fill the flask completely with water from the pneumatic trough. Loosen the screw and push the stopper into the flask as far as it will go. Wipe the flask dry and carefully remove the stopper. Pour most of the water from the flask into the 500 cubic centimeter graduate, and read the volume: the last portions of the water in the flask should be poured into the 25 cubic centimeter graduate, so that the volume can be read accurately. (See Fig. 101). Record the total volume of the flask as shown in (*d*).

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[1] The pyrogallic acid is a 10 per cent solution, and the potassium hydroxide 50 per cent.

(*b*) Measure exactly 10 cubic centimeters of pyrogallic acid in the small graduate (see Int. § 6 (3) (*d*)), and pour it into the flask. Add 20 cubic centimeters of potassium hydroxide solution, and insert the rubber stopper quickly and firmly. Tighten the screw. Shake the flask vigorously for a minute. Then invert it and watch the surface of the liquid for bubbles. If any appear, the apparatus leaks. Find the leak, if any, start the experiment again from (*b*), taking care to remedy the defect before the flask is shaken. If no bubbles appear, continue to shake at intervals from fifteen to twenty minutes. During this operation the oxygen is absorbed by the solution.

(*c*) Place the flask on its side in the water of the pneumatic trough, and open the screw, taking care (1) not to let any of the solution run out, (2) nor to let too much water run in, and (3) to keep the end of the rubber tube constantly below the surface. After the water has stopped running in, remove the flask from the trough. Open the flask, put a glowing stick into the gas, and observe the result. The gas is nitrogen. Measure carefully the volume of the final liquid in the flask.

(*d*) Record and calculate as follows: —

(a) Volume of original solution = 30 cc.
(b) Capacity of flask = cc.
(c) Volume of air taken (b − a) =
(d) Final volume of liquid =
(e) Volume of water which entered (d − a) =
(f) Per cent of water which entered (e ÷ c) =

But the per cent of entering water equals the per cent of gas absorbed, hence

(g) Per cent of oxygen =
(h) Per cent of nitrogen (100 − g) =

Experiment 26. — Air contains Water Vapor.

Prove by an experiment that air contains water vapor.

Experiment 27. — Air contains Carbon Dioxide.

(*a*) Expose a small bottle of limewater to the air. After a short time, examine the surface of the liquid. Describe the change. Explain it.

(*b*) If a blast lamp (or bicycle pump) is available, replace the lamp with a glass tube, and force air through a bottle half full of limewater, until a definite change occurs. Describe it. Explain it.

ACIDS, BASES, AND SALTS.

Experiment 28. — General Properties of Acids. *Materials:* Dilute sulphuric, nitric, and hydrochloric acids, glass rod, litmus paper (both colors), zinc.

Fill separate test tubes one third full of each of the acids. Label the tubes in some distinguishing manner.

(*a*) Dip a clean glass rod into each acid and *cautiously* taste it. Describe the taste by a single word.

(*b*) Dip a clean glass rod into each acid and put a drop on both kinds of litmus paper. The striking change is characteristic of acids; draw a general conclusion from it.

(*c*) Slip a small piece of zinc into each test tube successively. If no chemical action results, warm gently. Test the most obvious product by holding a lighted match inside of each tube. What gas comes from the hydrochloric and sulphuric acids?

(*d*) Summarize the general results of this experiment.

Experiment 29. — General Properties of Bases. *Materials:* Litmus paper (both colors), glass rod, sodium hydroxide and potassium hydroxide solutions, and ammonium hydroxide.

(*a*) Rub a little of each liquid between the fingers, and describe the feeling. *Cautiously* taste each liquid by touching to the tip of the tongue a rod moistened in each, and describe the result.

(*b*) Test each solution with litmus paper. Describe the result.

(*c*) Summarize the general results of this experiment.

(*d*) Compare acids and bases as to taste and to reaction with litmus.

Experiment 30. — A Property of Many Salts and All Neutral Substances. *Materials:* Litmus paper (both colors), glass rod, dilute solutions of sodium chloride, potassium nitrate, potassium sulphate, and barium chloride.

Test each solution with litmus paper. Describe the result. Compare with the litmus reaction of acids and bases.

Draw a general conclusion from this experiment.

Experiment 31. — The Nature of Common Substances.

Determine by the litmus test the nature of lemon juice, vinegar, sweet and sour milk, washing soda, borax, wood ashes, faucet water, baking soda, sugar, cream of tartar, the juice of any ripe fruit and any green fruit.

Make a solution of each of the solids before testing. Tabulate the results as follows: —

NATURE OF COMMON SUBSTANCES.

ACID.	ALKALINE.	NEUTRAL.

Experiment 32. — Neutralization. *Materials:* Sodium hydroxide (solid), hydrochloric acid, nitric acid, silver nitrate solution, blue litmus paper, glass rod, evaporating dish, gauze-covered ring.

Dissolve a small piece of sodium hydroxide in an evaporating dish half full of water. Slowly add dilute hydrochloric acid, until a drop taken from the dish upon a glass rod reddens blue litmus paper. Then evaporate to dryness by heating over a piece of wire gauze supported by a ring. Since the residue mechanically holds traces of the excess of hydrochloric acid added, it is necessary to remove this acid before applying any test. Heat the dish until all the yellow color disappears, then moisten the residue carefully with a few drops of warm water and heat again to remove the last traces of acid. This precaution is essential to the success of the experiment.

Test a portion of the residue with litmus paper to find whether it has acid, alkaline, or neutral properties. Taste a little. Test (*a*) a solution of the residue for a chloride, and (*b*) a portion of the solid residue for sodium. (See Exps. 12 (*b*) and 24.) Draw a definite conclusion from the total evidence.

HEAT, LIGHT, ELECTRICITY, AND CHEMICAL ACTION.

Experiment 33. — Heat and Chemical Action. *Materials:* Lime, evaporating dish, match.

Put a small piece of lime in an evaporating dish, and sprinkle a little water over it. Watch for a change. If no marked change soon occurs, add a little more water. Describe the change. Touch a match to the mass. Is there evidence of much heat? What caused the heat?

Experiment 34. — Heat and Chemical Action. *Materials:* Sulphur, powdered iron, dilute hydrochloric acid.

Put about 3 grams of sulphur and 3 grams of powdered iron in a test tube. Cover the mouth of the test tube with the thumb and shake until the two substances are well mixed. Attach the test tube to the holder and heat strongly in the flame. As soon as the sulphur melts and boils and the contents give evidence of decided chemical action, remove the test tube at once from the flame, and watch the change. Is there evidence of heat? Of increasing heat? Of much heat?

When the tube is cool, break the end, and examine the contents. Describe it. It is a compound called iron sulphide, and is the product of the chemical action which was started by heat. But the chemical action itself was so vigorous that it increased the heat.

The fact that the product differs from the original mixture may be shown as follows: Add dilute hydrochloric acid to a part of the product and also to a little of the original mixture, testing the gaseous product in each case by the odor. Is the odor the same?

State briefly how heat and chemical action are related, using this experiment as an illustration.

Experiment 35. — Light and Chemical Action. *Materials:* Potassium bromide, silver nitrate solution, funnel, filter paper, glass rod.

Dissolve a crystal of potassium bromide in a test tube one fourth full of water, add an equal volume of silver nitrate solution, and shake. The precipitate is silver bromide. Describe it. Filter (see Int. § 4). Remove the filter paper from the funnel, unfold it, and expose the silver bromide for a few minutes to the light — sunlight, if possible. Describe the change. What caused the change? How is this property of silver bromide utilized?

Experiment 36. — Electricity and Chemical Action. (Teacher's Experiment.)

Repeat Experiment 22.

Exercises for the Class:

(1) Define electrolysis, electrode, electrolyte, ion, anion, cation.

(2) State briefly the accepted explanation of the electrolysis of water.

(3) Is hydrogen an anion or cation? At what electrode does it collect?

(4) Answer the same questions (as in 3) about oxygen.

Experiment 37. — Electricity and Chemical Action. (Teacher's Experiment.) *Materials:* Starch, potassium iodide, mortar and pestle, filter paper, sheet tin (or iron), battery of two or more cells.

Grind together in a mortar a lump of starch and a crystal of potassium iodide. Add enough water to make a thin liquid. Dip a strip of filter paper into the mixture, and spread the wet paper upon a sheet of tin (or iron). Press the end of the wire attached to the zinc (of the battery) upon the tin, and draw the other wire across the sheet of paper. The marks are caused by iodine which is liberated from the potassium iodide and colors the starch.

Exercises for the Class:

(1) Describe briefly this experiment.

(2) Iodine is a non-metal. At what electrode is it liberated? Is iodine an anion or a cation?

CHLORINE.

(*Do not inhale chlorine.*)

Experiment 38. — Preparation of Chlorine. *Materials:* Concentrated hydrochloric acid, 30 grams manganese dioxide, bundle of fine brass wire, strip of calico, paper with writing in lead pencil and in ink, litmus paper (both colors), taper. The *apparatus* is shown in Figure 104. It is the same as that used to prepare hydrogen; and there are also needed four bottles, a wooden block (about 10 centimeters or 4 inches square) with a hole in the center, and four glass plates to cover the bottles.

Weigh the manganese dioxide upon a piece of paper creased lengthwise. Slip it into the test tube, *A* (see Int. § 6 (*e*)). Arrange the apparatus as shown in the figure. Pour enough concentrated hydrochloric acid through the safety tube to cover the manganese dioxide. Heat gently with a small flame, keeping the flame below the level of the contents of the test tube. Chlorine is rapidly evolved as a greenish gas, and passes into the bottle, *G*, which should be removed when full (as seen by the green color) and covered with a glass plate; the bottle may be easily removed by holding the block, *F*, in one hand and pulling the bottle, *G*, aside, bending the whole delivery tube at the same time at the rubber connection, *D*. If the evolution of gas slackens, add more acid through the safety tube. Collect four bottles, and perform the next experiment at once.

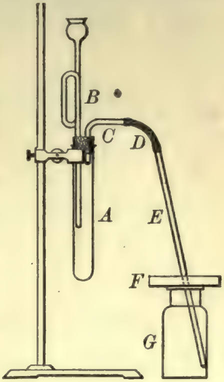

FIG. 104. — Apparatus arranged for preparing chlorine.

Experiment 39. — Properties of Chlorine.

Study as follows the gas prepared above: —

(*a*) Heat the bundle of brass wire and thrust it into a bottle of chlorine. Describe the result, especially the evidence of chemical action and of new products.

(*b*) Into a bottle of dry chlorine put a piece of calico, litmus paper (both colors), and paper containing writing in black and in red ink. Allow the whole to remain undisturbed for a few minutes and then describe the change, if any. Add several drops of water, and describe the change. Draw a general conclusion from the whole experiment.

(*c*) Hold a burning taper in a bottle of chlorine long enough to observe the result. Draw a conclusion. Verify it thus: Fold a strip of filter paper (about 10 centimeters or 4 inches wide) into the shape shown in Figure 105; cautiously heat[1] about 10 cubic centimeters of turpentine in a large test tube; saturate

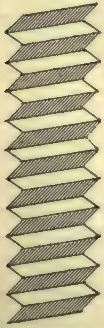

FIG. 105. — Fluted paper.

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[1] Hold the test tube with the holder. Remember that turpentine ignites easily. If the turpentine catches fire, press a damp towel over it.

the paper with the hot turpentine and drop it into a bottle of chlorine. Describe the result. When the action is over, examine the paper, and draw a conclusion regarding the action between hot turpentine and chlorine.

Wax (in the taper) and turpentine are mainly compounds of hydrogen and carbon. Explain the result in (*c*).

ANSWER:

(1) Many metals act like the brass in (*a*). What general conclusion can be drawn about the reaction of chlorine and metals?

(2) What is essential for the bleaching action of chlorine?

(3) What does (*c*) show about the attraction between chlorine and hydrogen?

(4) What class of chemical changes is illustrated by (*a*)? What classes by (*c*)?

(5) What class of chemical changes is illustrated by the preparation of chlorine?

(6) What three striking properties has chlorine? How can it be distinguished from all gases previously studied?

Experiment 40. — Bleaching by Bleaching Powder. *Materials:* Bleaching powder, sulphuric acid, calico.

Put a little bleaching powder into a test tube and add enough water to make a thin paste. Add a few drops of dilute sulphuric acid, and then dip a strip of bright-colored calico into the mixture. Remove the calico in a few minutes, and wash it with water. Describe the change in the calico.

Experiment 41. — Preparation of Hydrochloric Acid. *Materials:* The *apparatus* used in Experiment 38; 20 grams sodium chloride, concentrated sulphuric acid, pneumatic trough filled with water as usual, stick of wood, litmus paper (blue), ammonium hydroxide.

(*a*) Put 8 cubic centimeters of water in a small bottle or evaporating dish, cautiously add 12 cubic centimeters of concentrated sulphuric acid, and stir until the two are mixed. While this mixture is cooling, weigh the salt, slip it into the test tube, and then arrange the apparatus as shown in Figure 104. Pour half the cold acid mixture through the safety tube, let it settle through the salt, and then add the remaining acid. Heat gently with a low flame, as in the preparation of chlorine. Hydrochloric acid gas is evolved, and passes into the bottle, which should be removed when full, as directed under chlorine. A piece of moist blue litmus paper held at the mouth of the bottle will show when it is full. Collect these bottles, cover each with a glass plate, and set aside until needed.

(*b*) As soon as the third bottle of gas has been collected, removed, and covered, put in its place a bottle one fourth full of water. Adjust its height (if necessary) by wooden blocks so that the end of the delivery tube is just above the surface of the water. Continue to heat the generator at intervals, and the gas will be absorbed by the water. Shake the bottle occasionally.

Meanwhile study the gas already collected.

Experiment 42. — Properties of Hydrochloric Acid Gas.

Proceed as follows with the hydrochloric acid gas prepared by Experiment 41 : —

(*a*) Insert a blazing stick of wood into a bottle. Remove as soon as the change is noticed. Describe the change. Compare the action with the behavior of hydrogen and of oxygen under similar conditions.

(*b*) Hold a piece of wet filter paper near the mouth of the same bottle. Describe the result. What is the cause?

(*c*) Invert a bottle, and stand it upon the shelf of the pneumatic trough. Describe any change noticed inside the bottle after a few minutes. What property of the gas does the result illustrate? Verify the observation by a simple test applied to the contents of the bottle.

(*d*) Drop into the remaining bottle of gas a piece of filter paper wet with ammonium hydroxide. Describe the result. What name has the product?

(*e*) State other properties of hydrochloric acid gas which you have observed; *e.g.* color, odor, density.

Proceed at once with the next experiment.

Experiment 43. — Properties of Hydrochloric Acid.

Remove the bottle in which the hydrochloric acid gas is being absorbed (see Exp. 41 (*b*)), and study the solution as follows : —

(*a*) Determine its general properties, *e.g.* taste (cautiously), action with litmus, and with zinc.

(*b*) Add to a test tube half full of the hydrochloric acid a few drops of nitric acid and of silver nitrate solution. The white, curdy precipitate is silver chloride. Filter part of the contents of the test tube, and expose the precipitate to the sunlight. Describe the change which soon occurs. To the remaining contents of the test tube add ammonium hydroxide, and shake. Describe the result.

Experiment 44. — Tests for Hydrochloric Acid or a Chloride.

(*a*) What is a simple test for hydrochloric acid gas or for concentrated hydrochloric acid?

(*b*) What is the usual test for hydrochloric acid?

(*c*) Dissolve a little sodium chloride in a test tube half full of water, and apply the test designated in (*b*). (Suggestions. See Exps. 12 (*b*) and 43 (*b*).)

COMPOUNDS OF NITROGEN.

Experiment 45. — Preparation of Ammonia. *Materials*: 15 grams lime, 15 grams ammonium chloride, 3 bottles, 2 glass plates, pneumatic trough filled as usual, litmus paper, stick of wood, filter paper. The *apparatus* is shown (in part) in Figure 106. The large test tube, *A*, is provided with a one-hole rubber stopper to which is fitted the right-angle bend, *C*, connected with a short glass tube, *B* (12 centimeters or 5 inches long), by the rubber tube, *D*.

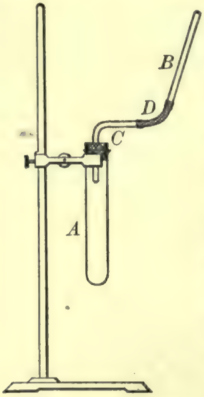

FIG. 106. — Apparatus for preparing and collecting ammonia gas.

(*a*) Weigh the lime and ammonium chloride separately, mix them thoroughly on a piece of paper, and slip the mixture into the test tube to which a little water has been previously added. Add a little water. Quickly insert the stopper with its tubes, and clamp the test tube as shown in the figure (taking care not to crush the test tube).

Slip the glass delivery tube, *B*, into a bottle, invert the bottle, and hold it so that the tube is in the position shown in the figure. Heat the test tube gently with a low flame, beginning near the top of the mixture and gradually working downward. Ammonia gas will pass up into the bottle, which should be removed when full and covered with a glass plate. A piece of moist red litmus paper held near the mouth will show when the bottle is full. *Do not smell at the mouth of the bottle*. Collect two bottles and set aside until needed.

(*b*) As soon as the last bottle has been collected, rearrange the apparatus to absorb the ammonia gas in water, as in the case of hydrochloric acid (see Exp. 41 (*b*)). Replace the short glass tube by the delivery tube, *E*, which should pass through the wooden block, *F*, into a bottle, *G*, one fourth full of water, so that the end is just above the surface of the water (see Fig. 104). Continue to heat the generator at intervals, and the gas will be absorbed by the water. Shake the bottle occasionally.

While the solution is being prepared, study the gas already collected.

Experiment 46.— Properties of Ammonia Gas.

Proceed as follows with the ammonia gas prepared in Experiment 45 : —

(*a*) Test the gas in one bottle with moist litmus paper and with a blazing stick. Describe the result. Compare the action with the behavior of hydrogen, oxygen, and hydrochloric acid gas, under similar circumstances.

(*b*) Invert the same bottle and stand it upon the shelf of the pneumatic trough. Describe any change noticed inside the bottle. What property of the gas is revealed? Is it a marked property? Test the contents of the bottle with litmus paper (both colors).

(*c*) Pour a few drops of concentrated hydrochloric acid into an empty, warm, dry bottle. Roll the bottle until the inside is well coated. Cover it with a glass plate, invert it, and stand it upon a covered bottle of ammonia gas. Remove both plates at once, and hold the bottles together by grasping them firmly about their necks. Describe the action, giving all the evidence of chemical action. What is the white product?

Experiment 47.— Properties of Ammonium Hydroxide.

Remove the bottle in which the ammonia gas is being absorbed (see Exp. 45, (*b*)), and study the resulting ammonium hydroxide as follows :—

(*a*) Determine the general properties, *e.g.* taste and odor (cautiously), feeling, action with litmus.

(*b*) Warm a little in a test tube. What gas is evolved?

(*c*) Try the effect of ammonium hydroxide on a grease spot. Describe the result.

Experiment 48.— Neutralization of Ammonia. *Materials:* Ammonium hydroxide, hydrochloric acid, evaporating dish, sodium hydroxide solution, litmus paper, gauze-covered ring.

Fill an evaporating dish one fourth full of ammonium hydroxide, and slowly add dilute hydrochloric acid, stirring constantly, until the solution is just neutral or faintly acid. Evaporate to dryness, very slowly, on a gauze-covered ring. Test the residue as follows:—

(*a*) Is it an acid, alkali, or salt?

(*b*) Warm a little with sodium hydroxide solution. What is formed? Draw a conclusion as to the nature of the residue.

(*c*) Support the dish on the gauze and warm gently until a decided change occurs. Describe the result. What compound do the fumes suggest?

(*d*) Verify the observations and conclusions by repeating (*b*) and (*c*) with ammonium chloride from the laboratory bottle.

(*e*) What is the main product of the interaction of ammonium hydroxide and hydrochloric acid?

Experiment 49.— Preparation of Nitric Acid. *Materials:* Glass stoppered retort, sand bath pan and sand, bottle, 30 grams sodium nitrate, 20 cubic centimeters concentrated sulphuric acid, funnel.

Weigh the sodium nitrate and slip it into the retort (see Int. § 6 (1) (*c*)). Attach the retort by a clamp to an iron stand so that (1) *its bulb* rests on the sand bath, supported by a ring, and (2) *the end of its neck* passes into an inclined bottle which rests on the table. The nitric acid which is generated in the bulb will pass down the neck and condense, partly in the neck and partly in the bottle. The bottle should be partially covered with a piece of wet filter paper, especially where the neck of the retort enters. It is advisable, though not always necessary, to place a block of wood against the bottom of the bottle to keep it in the desired position.

Slip a funnel through the tubulure of the retort as far as it will reach, and pour the acid through the funnel into the retort. Remove the funnel and insert the stopper of the retort tightly. Heat gently. Brown fumes will appear in the retort, and nitric acid will pass into the receiver. Distil at as low a temperature as possible, as long as any nitric acid runs down the neck of the retort.

Pour the nitric acid into a test tube or small bottle for use in Experiment 50.

Allow the contents of the retort to cool, add a little warm water, let the whole stand until the contents are loosened, and then pour into a bottle for use in Experiment 53.

Experiment 50. — Properties of Nitric Acid. *Materials:* Quill toothpick, indigo solution. Add twice its volume of water to the nitric acid prepared in Experiment 49, and proceed as follows: —

(*a*) Boil a piece of a quill toothpick in a portion of this diluted nitric acid. How is the quill changed at first? What is the effect of continued heating? Pour off the acid, and wash the quill with water. Is the color permanent?

(*b*) Add a dozen or more drops of nitric acid to a *dilute* solution of indigo. Describe the change. Will ammonium hydroxide restore the original color? Is the change temporary or permanent? What, in all probability, is the general character of the change — combination or decomposition? Draw a general conclusion from (*a*) and (*b*) regarding the action of nitric acid on organic matter, which is typified by the quill and indigo.

EXERCISES:

(1) What color has nitric acid?

(2) Examine a bottle of nitric acid which has been standing in the laboratory. What can be said of the stability of nitric acid?

(3) State other properties of nitric acid you have observed.

Experiment 51. — Test for Nitric Acid and Nitrates. *Materials:* Concentrated nitric and sulphuric acids, ferrous sulphate, sodium nitrate.

To a test tube one fourth full of water add a little concentrated nitric acid and shake. Add an equal volume of concentrated sulphuric acid. Shake until the acids are well mixed, then cool by holding the test tube in running water. Make a cold, dilute solution of fresh ferrous sulphate and pour this solution carefully down the side of test tube upon the nitric acid mixture. Where the two solutions meet, a brown or black layer will appear, consisting of a compound formed by the interaction of the nitric acid and the ferrous sulphate. It is an unstable compound and will often decompose if the test tube is shaken. Record the observation.

This test is also used for a nitrate. Try it with a solution of sodium nitrate. Record the result.

Experiment 52. — A Special Test for Nitrates. *Materials:* Charcoal, block of wood, potassium nitrate.

Heat a piece of charcoal in the Bunsen flame, lay it on a block of wood or an iron pan, and cautiously sprinkle powdered potassium nitrate upon the hot surface. Stand back when the action begins. Observe and describe the action, especially its violence and rapidity, also the color of the flame, the effect on the charcoal, and any other characteristic result. This kind of chemical action is called *deflagration*. What causes it?

Experiment 53. — The Solid Product of the Interaction of Sodium Nitrate and Sulphuric Acid. *Materials:* Residue from Experiment 49, evaporating dish, glass rod, gauze-covered ring, distilled water, barium chloride solution, ferrous sulphate, concentrated sulphuric acid.

Pour the solid residue obtained in Experiment 49 into an evaporating dish, and evaporate to dryness over a piece of wire gauze in the hood. As the mass approaches pasty consistency, lessen the heat to avoid spattering. When the mass is dry, heat strongly as long as white, choking fumes are evolved. This last operation is done to remove all traces of sulphuric acid, and to complete the chemical change. Allow the dish to cool gradually, and when cool, dissolve some of the white solid in distilled water and test separate portions for a sulphate and nitrate (see Exps. 12 (*c*) and 51). Which is it? Test another portion for sodium (see Exp. 24 (*d*)). What is the name of the white substance?

Draw a general conclusion regarding the chemical action which occurs in the preparation of nitric acid by the interaction of sulphuric acid and sodium nitrate.

Experiment 54. — Interaction of Nitric Acid and Metals. *Materials:* Zinc, copper, tin, iron, concentrated nitric acid.

Stand four test tubes in the test-tube rack, and slip into each a few small pieces of one of the following metals: zinc, copper, tin, and iron. Add to each test tube in succession enough concentrated nitric acid to cover the metal. Observe the changes, particularly (1) the vigor of the action, (2) the nature and properties of the products, especially color and solubility, and (3) evidence of the evolution of hydrogen. Tabulate these observations.

Experiment 55. — Interaction of Nitric Acid and Copper, and Study of Nitric Oxide and Nitrogen Peroxide. — *Materials:* 10 grams copper (borings or fine pieces of sheet metal), concentrated nitric acid, pneumatic trough filled as usual, three bottles, three glass plates, matches, piece of wire (15 centimeters or 6 inches long); and the *apparatus* used in Experiment 8.

Arrange the apparatus as in Experiment 8, after putting the copper into the test tube (see Fig. 103). Insert the stopper tightly, adjust the delivery tube, fill three bottles with water, and invert them in the trough. Pour just enough concentrated nitric acid through the safety tube into the flask to cover the copper, taking care to seal the bend of the safety tube with acid. Dense brown fumes are evolved. If the action is too vigorous, add a little water through the safety tube. Collect three bottles of the gas which bubbles from the delivery tube. Cover them with glass plates and stand them aside until needed. Pour the blue liquid in the test tube into an evaporating dish, and evaporate slowly to crystallization (not to dryness) on a gauze-covered ring in the hood. The crystals, after being dried between filter paper, should be preserved in a well-stoppered bottle.

While the solution is evaporating, study the gas as follows: —

(*a*) Observe its general properties while covered.

(*b*) Uncover a bottle. Describe the result. Is the brown gas identical in color with the one observed in the generator at the beginning of the experiment?

(*c*) Uncover a bottle, pour in about 25 cubic centimeters of water, cover with the hand and shake vigorously, still keeping the bottle covered. Why has the brown gas disappeared? Uncover the bottle for an instant, then cover and shake again. Is the result the same? Repeat, if the result is not definite, or does not agree with previous observations.

(*d*) With the third bottle determine whether the two gases will burn or support combustion. A convenient flame is a burning match fastened to a stiff wire. Plunge it quickly to the bottom at first and gradually raise it into the brown gas.

ANSWER:

(1) What is the source of the colorless gas? What is its name? What is the name of the brown gas?

(2) What is the general chemical relation of the two gases to each other? To the air?

(3) Why is not the brown gas collected in the bottles by displacement of water?

(4) Will either gas burn or support combustion?

(5) Which gas has been observed before? In what experiment?

(6) What is the general relation of these gases to nitric acid?

Study the properties of the crystals by determining: —

(*a*) Solubility in water (cold and hot).

(*b*) Action of heat.

(*c*) Action of their solution upon an iron nail.

(*d*) Action of their solution when added to ammonium hydroxide.

(*e*) Presence of a nitrate.

Compare the observed properties with those of copper nitrate obtained from the laboratory bottle. Are the two substances identical?

Experiment 56. — Preparation and Properties of Nitrous Oxide. *Materials:* Ammonium nitrate, pneumatic trough filled, as usual, with warm water, three bottles, three glass plates, sulphur, deflagrating spoon, stick of wood. The apparatus is shown in Figure 107. The parts lettered *A*, *C*, *D*, *E* have been used before; *B*, *F*, *G*, *H* are exactly the same as *A*, *C*, *D*, *E* respectively. (See page 504.)

Construct and arrange the apparatus as shown in the figure. Fill the large test tube, *A*, about half full of ammonium nitrate. The large test tube, *B*, remains empty. The end of *H* rests on the bottom of the pneumatic trough as usual. It is desirable, though not absolutely necessary, to fill the trough and bottles with *warm* water. Be sure the apparatus is gas-tight.

Heat *A* gently with a low flame (5 centimeters or 2 inches). Adjust the apparatus if it leaks. The ammonium nitrate melts and appears to boil. Regulate the heat so that the evolution of the nitrous oxide will be slow. Notice the fumes which collect in *A*, and the liquid which collects in *B*. Prepare three bottles of nitrous oxide, free from air, covering each with a glass plate as soon as removed from the trough. When the last bottle has been collected and covered, remove the end of the delivery tube from the trough.

Test the gas as follows: —

(*a*) Allow a bottle to remain uncovered for a few seconds. How does nitrous oxide differ from nitric oxide?

(*b*) Thrust a glowing stick of wood into the same bottle of gas. Describe the result. Is the gas combustible? Does it support combustion?

(*c*) The observations in (*b*) suggest that the gas is oxygen, but it is not, though this fact is not easily proved by a single experiment. Put a small piece of sulphur in a deflagrating spoon, light it, and lower the burning sulphur *at once* into another bottle of gas. If the experiment is conducted properly, the sulphur will not burn so brightly as it would in a bottle of oxygen.

(*d*) Stand the other bottle mouth downward in the pneumatic trough, or better, in a vessel of cold water. Describe the result. If the result is not conclusive, fill the bottle half full of water, cover with the hand, and shake. Does this observation help distinguish the gas from oxygen?

What in all probability is the other product (seen in *B*) of the chemical change in this experiment? Could it have been an impurity in the ammonium nitrate? What are the fumes noticed in *A*?

How would you distinguish ammonium nitrate from all other nitrates? How would you distinguish nitrous oxide from (*a*) the other oxides of nitrogen, (*b*) air, (*c*) oxygen, (*d*) hydrogen, (*e*) nitrogen, (*f*) carbon dioxide?

Experiment 57. — Preparation and Properties of Sodium Nitrite. *Materials:* 10 grams sodium nitrate, 20 grams lead, iron sand bath pan, glass rod.

Heat the mixture of lead and sodium nitrate on the sand bath pan, which stands on the ring of an iron stand. Stir the melted mass with a glass rod. Some of the lead will disappear and a yellowish brown powder will be seen in the molten mass. The action should proceed until most of the lead has disappeared. Allow the mass to cool, transfer to a mortar, pulverize, add hot water, and filter the clearer portion; add more hot water to the residue, and filter this portion. This operation extracts the sodium nitrite. Add to the combined filtrates several drops of concentrated sulphuric acid. Describe the result. How does the result compare with the action of concentrated sulphuric acid on sodium nitrate? The yellowish product is lead oxide. What general chemical change led to its formation? How must the nitrate have been changed?

Experiment 58. — Aqua Regia. *Materials:* Gold leaf, concentrated nitric and hydrochloric acids, glass rod.

Touch a small piece of gold leaf with the end of a moist glass rod, and wash the gold leaf into a test tube by pouring a few cubic centimeters of concentrated hydrochloric acid down the rod. Heat gently until the acid just begins to boil. Does the gold dissolve? Wash another piece of gold leaf into another test tube with concentrated nitric acid, and heat as before. Does the gold dissolve? Pour the contents of one tube into the other, and warm gently. Does the gold dissolve? Draw a conclusion.

ANSWER:

(1) What is the literal meaning and significance of the term *aqua regia?*

(2) What other metals does *aqua regia* dissolve?

(3) What is the chemical action of *aqua regia* on gold?

(4) Upon what property of nitric acid does the action of *aqua regia* depend?

CARBON.

Experiment 59. — Distribution of Carbon. *Materials:* Hessian crucible, sand, wood, cotton, starch, sugar, glass tube (or rod), candle, block of wood.

(*a*) Cover the bottom of a Hessian crucible with a thin layer of sand. Put on the sand a small piece of wood, a small, compact wad of cotton, and a lump of starch. Fill the crucible loosely with dry sand, and slip it into the ring of an iron stand. Heat with a flame which extends just above the bottom of the crucible until the smoking ceases (approximately 20 minutes). After the crucible has cooled sufficiently to handle, pour the contents out upon a block of wood or an iron pan. Examine the contents. What is the residue? What is hereby shown about the distribution of carbon?

While the crucible is heating, do the following: —

(*b*) Heat about 1 gram of sugar in an old test tube until the vapors cease to appear. What is the most obvious product?

(*c*) Close the holes at the bottom of a lighted Bunsen burner, and hold a glass tube in the upper part of the flame long enough for a thin deposit to form. Examine it, name it, and state its source.

(*d*) Hold a glass tube in the flame of a candle which stands on a block of wood, and compare the result with that in (*c*).

Draw a general conclusion regarding the distribution of carbon.

Experiment 60. — Decolorizing Action of Charcoal. *Materials:* Animal charcoal, indigo solution, filter paper and funnel.

Fill a test tube one fourth full of powdered animal charcoal as follows: Fold a narrow strip of smooth paper so that it will slip easily into the test tube; place the powder at one end of the troughlike holder, slowly push the paper into the test tube, holding both tube and paper in a horizontal position; now hold the tube upright, and the powder will slip from the paper. Add 10 cubic centimeters of indigo solution, shake thoroughly for a minute, and then warm gently. Filter through a wet filter paper into a clean test tube. Compare the color of the filtrate with that of the indigo solution. Explain the change in color.

Other organic substances besides indigo are similarly changed. Draw a general conclusion regarding the decolorizing power of charcoal.

Experiment 61. — Deodorizing Action of Charcoal. *Materials:* Wood charcoal, hydrogen sulphide solution, test tube, and cork.

Smell of a weak solution of hydrogen sulphide gas. Fill a test tube half full of powdered wood charcoal as in Experiment 60, add a little hydrogen sulphide solution, and cork securely. If the tube leaks, make the opening gas-tight with vaseline. Shake thoroughly. After fifteen or twenty minutes, remove the stopper and smell of the contents. Is the odor much less offensive? Repeat, unless a definite result is obtained. Explain the change.

Experiment 62. — Preparation of Carbon Dioxide. *Materials:* Lumps of marble, sand, concentrated hydrochloric acid, stick of wood, candle fastened to a wire, limewater, four bottles. Use the same *apparatus* as in the preparation of hydrogen (see Exp. 8).

Cover the bottom of the test tube with sand, add a little water, and carefully slip into it half a dozen small lumps of marble. Arrange the apparatus to collect the gas over water, as previously directed. Add through the safety tube just enough concentrated hydrochloric acid to cover the marble. Collect four bottles, cover with glass plates or wet filter paper, and stand aside till needed.

Allow the action in the flask to continue, and preserve the contents for Experiment 64.

Proceed at once to the next experiment.

Experiment 63. — Properties of Carbon Dioxide.

Study the properties of carbon dioxide gas as follows: —

(*a*) Plunge a burning stick several times into one bottle. Describe the result.

(*b*) Lower a lighted candle into a bottle of air, and invert a bottle of carbon dioxide over it, holding the bottles mouth to mouth. Describe the result. What does this result show about the density of carbon dioxide?

(*c*) Pour a little limewater into a bottle of carbon dioxide, cover with the hand, and shake vigorously. Describe and explain the result.

(*d*) Fill a bottle of carbon dioxide one third full of water, cover tightly with the hand, and shake vigorously. Invert, still covered, in the pneumatic trough. Does the result reveal any facts about the solubility of carbon dioxide?

EXERCISES:

(1) Describe the preparation of carbon dioxide.

(2) What do (*a*) and (*b*) show about the relation of carbon dioxide to combustion?

(3) What is the test for carbon dioxide?

(4) What chemical changes occur in the test for carbon dioxide?

Experiment 64. — The Solid Product of the Interaction of Calcium Carbonate and Hydrochloric Acid.

Filter the contents of the test tube into an evaporating dish, adding a little warm water beforehand, if the contents are solid. Evaporate to dryness in the hood over a free flame as long as much liquid remains. As the residue approaches pasty consistency, add a little water, stand the dish on a gauze-covered support, and move the lighted burner underneath. Heat the residue until no fumes of hydrochloric acid are evolved. Dissolve some of the residue in distilled water and test portions for (*a*) a chloride and (*b*) a calcium compound (see Exp. 12 (*b*), (*d*)). If a calcium compound is found, confirm the observation thus: Dip a clean, moist platinum test wire (see Int. § 5 (4)) into the solid residue, and hold it in the Bunsen flame. If calcium is present, the flame will be colored a yellowish red.

What is the residue? Verify the conclusion by a simple experiment.

Experiment 65. — Carbon Dioxide and Combustion. *Materials:* Limewater, glass tube, candle attached to wire, stick of wood, two bottles.

(*a*) Exhale through a glass tube into a test tube half full of limewater. Describe and explain the result.

(*b*) Lower a lighted candle into a bottle and allow it to burn for a few minutes. Remove the candle, pour a little limewater into the bottle, and shake vigorously. Describe and explain the result.

(*c*) Allow a stick of wood to burn for a short time in a bottle (not the one used in (*b*)), and then proceed as in (*b*). Describe the result. Does it confirm the results obtained in (*a*) and (*b*)?

(*d*) Repeat (*c*), using a piece of paper in place of the wood. Describe the result. Does it confirm the results obtained in (*a*), (*b*), and (*c*)?

ANSWER:

(1) What is the source of the carbon dioxide in (*a*)?

(2) What is one of the gases escaping from chimneys? From a burning lamp?

Experiment 66. — Carbonic Acid. (Teacher's Experiment.) *Materials:* Solutions of sodium hydroxide and phenolphthalein, bottle, and the carbon dioxide generator used in Experiment 62.

Construct and arrange the carbon dioxide generator as in Experiment 62. Fill the bottle nearly full of water, add a few drops of a solution of phenolphthalein[1] and just enough sodium hydroxide solution to color the liquid a faint magenta. Allow a *slow* current of carbon dioxide to bubble through the liquid in the bottle, until a definite change is produced in the absorbing liquid. Describe and explain it.

Experiment 67. — Preparation and Properties of Carbonates. *Materials:* Marble, sand, concentrated hydrochloric acid, limewater. The *apparatus* is the same as that used in Experiment 62.

(*a*) Prepare a carbon dioxide generator as in Exp. 62, and attach it by a clamp to an iron stand so that the end of the delivery tube reaches to the bottom of a bottle half full of limewater. Pass the gas *slowly* into the limewater until considerable precipitate is formed. Remove the bottle and let the precipitate settle.

(*b*) Meanwhile pass carbon dioxide *slowly* for about five minutes into a test tube nearly full of a dilute solution of sodium hydroxide.

(*c*) Examine the precipitate from (*a*) as follows: Pour off most of the liquid without disturbing the solid (see Int. § 6 (1) (*a*)). Dip a glass tube into limewater, remove it, and a drop will adhere to the end.

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[1] This compound is magenta in alkaline solutions and colorless in acid solutions.

Pour a little hydrochloric acid into the test tube, shake, and hold the "limewater tube" in the escaping gas. Observe the change in the drop of limewater. If no change occurs, add more acid to the precipitate. What is the liberated gas? What is the precipitate? How was the latter formed?

(*d*) Proceed as in (*c*) with the solution obtained in (*b*). What is the liberated gas? From what compound did it come? How was this compound formed? How does it differ from the one formed in (*a*)?

ANSWER:

(1) What is the test for a carbonate?

(2) How may limewater be distinguished from a solution of sodium or potassium hydroxide?

Experiment 68. — Detection of Carbonates. *Materials:* Hydrochloric acid, limewater, glass tube; baking soda, washing soda, baking powder, native chalk, tooth powder, white lead, whiting, old mortar (or plaster).

Put a little of each of the above solids in separate test tubes, add a little water and dilute hydrochloric acid, and shake; hold the "limewater tube" in the escaping gas, as in Experiment 67. If the action is not marked, warm the test tube. Describe the result in each case.

Experiment 69. — Acid Calcium Carbonate. *Materials:* Limewater and the carbon dioxide generator used in Experiment 62.

Pass carbon dioxide into a test tube half full of limewater until the precipitate disappears. Filter, if the liquid is not perfectly clear, and then heat. Describe the change. Explain the three changes which take place in the test tube.

Experiment 70. — Preparation and Properties of Carbon Monoxide. (Teacher's Experiment.) *Materials:* Oxalic acid, concentrated sulphuric acid, limewater, pneumatic trough filled as usual, three bottles, three glass plates. The *apparatus* is shown in Figure 107 (p. 504).

Precaution. *Carbon monoxide and oxalic acid are poisonous. Hot sulphuric acid is dangerous. Perform this experiment with unusual care.*

Put 10 grams of oxalic acid in the large test tube, *A*, and add 25 cubic centimeters of concentrated sulphuric acid. Put enough limewater in *B* to cover the end of the tube, *E*. The end of *H* should rest on the bottom of the pneumatic trough just beneath the hole in the shelf. Heat the tube, *A*, gently, and carbon monoxide will be evolved. A small flame must be used, because the gas is rapidly evolved as the heat increases. It is advisable to remove or lower the flame as bubbles appear in the tube, *B*, — *regulate the heat by the effervescence.* Collect all the gas, but do *not* use the first bottle, covering the bottles with glass plates as they are filled, and setting them aside temporarily. When the last bottle has been collected and covered, loosen the stopper in *B*, remove the end of *H* from the water in the trough, and if gas is still being evolved, stand the whole apparatus in the hood.

Test the gas thus: —

(*a*) Notice that it is colorless.

(*b*) Hold a lighted match at the mouth of a bottle for an instant. Note the flame, especially its color and how it burns. After the flame has disappeared, drop a lighted match into the bottle. Describe the result. Draw a conclusion and verify it by (*c*).

(*c*) Burn another bottle of gas, and after the flame has disappeared pour limewater into the bottle and shake. Describe the result.

EXERCISES FOR THE CLASS:

(1) What gas besides carbon monoxide was produced, as shown by *b*?

(2) Summarize the observed properties of carbon monoxide.

(3) What is the chemical relation of the two oxides of carbon?

(4) How can the two oxides be changed into each other? What two general processes do the changes illustrate?

Experiment 71. — Preparation and Properties of Ethylene. (Teacher's Experiment.) *Materials:* Alcohol, concentrated sulphuric acid, sand, pneumatic trough filled as usual, two bottles, limewater. The *apparatus* is that used in Experiment 70.

Precaution. *A mixture of ethylene and air explodes, if ignited. Hot sulphuric acid is dangerous. Guard against flames, leaks, and breakage.*

Put 5 cubic centimeters of water in a test tube and slowly pour upon it 15 cubic centimeters of concentrated sulphuric acid. Cool the acid by holding the test tube in a stream of cold water. Put 5 to 7 cubic centimeters of alcohol in the test tube, *A*, add a little clean sand, and then slowly pour in the *cold* acid. The test tube, *B*, remains empty. A dish should stand under *A* to catch the contents, in case of accident.

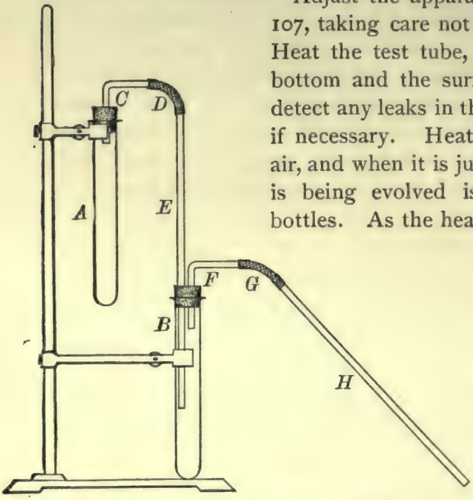

FIG. 107. — Apparatus for preparing ethylene.

Adjust the apparatus as shown in Figure 107, taking care not to crush the test tubes. Heat the test tube, *A*, gently between the bottom and the surface of the contents to detect any leaks in the apparatus. Readjust, if necessary. Heat gently to drive out the air, and when it is judged that the gas which is being evolved is ethylene, collect two bottles. As the heat increases, the mixture is apt to froth or "bump"; sometimes the gas is evolved suddenly. Hence the heat must be so regulated that the evolution of gas is slow. Especial care must be taken not to heat the test tube above the surface of the contents, otherwise a sudden movement of the hot liquid might crack the test tube. As soon as the gas has been collected, remove the tube, *H*, from the water, and if the ethylene is still being evolved, stand the apparatus in the hood. When the tube, *A*, is cool enough to handle, pour the contents down the sink or into a receptacle especially provided for dangerous mixtures.

Test the gas by holding a lighted match at the mouth of a bottle. Observe and record the color and temperature of the flame, its luminosity, rapidity of combustion, visible products, and any other characteristic properties. Repeat with the other bottle, and carefully observe properties needing confirmation. Add a little limewater to one of the bottles in which the gas was burned, shake, and explain the result. What evidence does this experiment present regarding the composition of ethylene?

Experiment 72. — Preparation and Properties of Acetylene.

Fill a test tube nearly full of water, stand the test tube in a rack, and drop two or three very small pieces of calcium carbide into the test tube. Acetylene is evolved. After the action has proceeded long enough to expel the air, light the gas by holding a lighted match at the mouth of the tube. Observe and record the nature of the flame, especially its color, intensity, visible products (if any), temperature, etc. Hold a cold glass plate or bottle over the flame. What does the result suggest about the composition of acetylene? What other evidence of its composition is revealed by the properties of the flame?

Experiment 73. — Preparation and Properties of Illuminating (Coal) Gas. (**Teacher's Experiment.**) *Materials:* Soft coal, asbestos, pneumatic trough filled as usual, three bottles, litmus paper, filter paper, lead acetate (or nitrate) solution. The *apparatus* is shown in Figure 108. *AA′* is an ignition tube from 10 to 15 centimeters (4 to 6 inches) long. A spiral of copper wire is placed near *A′*, and the tube is supported by a clamp between the wire and the end of the tube. An empty test tube or bottle is connected with the combustion tube by a bent tube passing to the bottom of *B*; this vessel retains tarry matter, which comes from the ignition tube. The U-tube contains moistened pink litmus paper in the limb *C*, and a narrow strip of filter paper moistened with a lead compound (nitrate or acetate) in the limb *C′*, the latter serving to detect hydrogen sulphide. The bottle, *D*, which may be any convenient size, is connected as shown in the figure, and is to be one third full of limewater. The tube, *E*, is to be connected with a delivery tube passing into a pneumatic trough arranged to collect a gas over water.

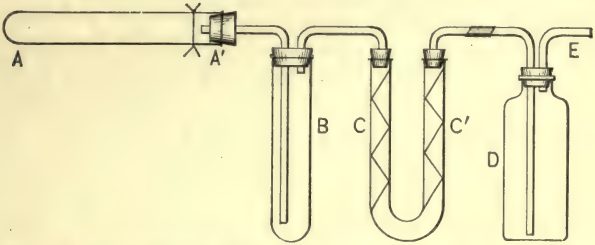

FIG. 108. — Apparatus for preparing illuminating gas from soft coal.

Fill *AA′* two thirds full of coarsely powdered soft coal, which should be held in place with a loose plug of shredded asbestos. See that all connections are gas-tight by heating the ignition tube gently; if the apparatus is tight, the expanded air will bubble through the bottle *D*. Readjust, if necessary.

Heat the whole ignition tube gently at first, and gradually increase the heat, but avoid heating either end very hot, otherwise the closed end may soften and burst or the rubber stopper may melt. As the heat increases, watch for marked changes in *B*, *CC′*, and *D*. As soon as the slow bubbling shows that all air has been driven out of the apparatus, collect, as previously directed, two bottles of the gas evolved. Cover the bottles with wet filter paper as soon as they are removed from the trough. When the last bottle has been removed, disconnect the apparatus at any convenient point between *A′* and *C′*. Let the ignition tube cool.

Test the gas by holding a lighted match near the mouth of a bottle. Observe and record the color and heat of the flame. Is smoke formed? Repeat with the remaining bottle, and observe more closely any facts suggested, but not clearly shown, by the first observations.

Examine the contents of the ignition tube. Does it resemble coke or some form of carbon? Examine the bottle, *B*, for tarry matter. Does the paper in *C* show the formation of ammonia? If the paper in *C′* is black or brown, it is caused by lead sulphide, which is formed by the interaction of hydrogen sulphide and a lead compound. Did the gas contain hydrogen sulphide? Did the bottle, *D*, show the formation of carbon dioxide?

EXERCISES FOR THE CLASS:

(1) Describe briefly the whole experiment.
(2) Sketch the apparatus.
(3) Summarize the properties of coal gas.

Experiment 74. — Combustion of Illuminating Gas. *Materials:* Pointed glass tube (see Int. § 3 (*c*)), bottle, limewater.

Attach a pointed glass tube to the rubber tube connected with the gas jet, and lower a small flame into a cold, dry bottle. Observe at once the most definite result inside the bottle. Remove and extinguish the flame, add a little limewater to the bottle, and shake. What are the two products of the combustion of coal gas? What do the observations show about the composition of the main constituents of coal gas?

Experiment 75. — Construction of a Bunsen Burner.

Take apart a Bunsen burner and study the construction. Write a short description of the burner. Sketch the essential parts.

Experiment 76. — Bunsen Burner Flame. *Materials:* Glass tube, powdered wood charcoal, pin, copper wire, wire gauze.

I. (*a*) Close the holes at the bottom of a Bunsen burner and hold a glass tube in the upper part of the flame. Note the black deposit. What is it? Where did it come from? Open the holes and hold the blackened tube in the colorless flame. What becomes of the deposit? How is the flame changed, if at all? What does the experiment suggest about the luminosity of flame?

(*b*) Dip a glass tube a short distance into powdered wood charcoal, place the end containing the charcoal in one of the holes at the bottom of the burner, and blow gently two or three times into the other end. Describe and explain the result. Does it verify the answer to the last question in (*a*)?

(*c*) Open and close the holes of a lighted burner several times. Describe the result. Pinch the rubber tube to extinguish the flame, then light the gas at the holes. What change is produced in the flame? What causes the change?

ANSWER:

(1) What is the object of the holes?
(2) Why does the gas burn at the top and not inside of the burner?
(3) Why does the flame sometimes "strike back" and burn inside?
(4) Why is the Bunsen flame nonluminous?

II. (*a*) Hold a match across the top of the tube of a lighted Bunsen burner. When it begins to burn, remove and extinguish it. Note where it is charred, and explain the result. Press a piece of wire gauze down upon the flame. Describe the appearance of the gauze. The same fact may be shown by sticking a pin through a (sulphur) match, suspending it across the burner, and then lighting the gas. The position of the match is shown in Figure 109. Turn on a full current of gas before lighting it. What does the whole

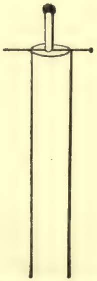

FIG. 109. — Sulphur match suspended across the top of a Bunsen burner.

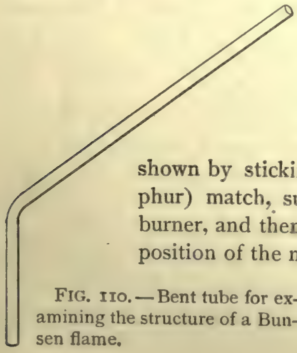

FIG. 110. — Bent tube for examining the structure of a Bunsen flame.

experiment show about the structure of the lower part of the Bunsen flame? Verify your answer by (*b*).

(*b*) Bend a glass tube about 15 centimeters (6 inches) long into the shape shown in Figure 110. Hold the shorter arm in the flame about 2 centimeters (1 inch) from the top of the burner tube. Hold a lighted match for an instant at the upper end of the tube. What does the result show about the structure of the Bunsen flame? Does it verify (*a*)?

(*c*) Find the hottest part of the flame, when a full current of gas is burning, by holding a copper wire in the flame. Measure its distance, approximately, from the top of the burner tube.

(*d*) Examine a typical Bunsen flame — one which shows clearly the outlines of the inner part. What is the general shape of each main part? Draw a vertical and a cross section of the flame.

Experiment 77. — Candle Flame. *Materials:* Candle, two blocks of wood, bottle, piece of stiff white paper, limewater, matches, lamp chimney, copper wire (15 centimeters or 6 inches long).

Attach a candle to a block of wood by means of a little melted candle wax, and proceed as follows:—

(*a*) Hold a cold, dry bottle over the lighted candle. Describe the result produced inside the bottle. What is the product? What is its source? Remove the bottle, pour a little limewater into it, and shake. Describe and explain the result. What are the two main products of a burning candle?

(*b*) Blow out the candle flame, and immediately hold a lighted match in the escaping smoke. Does the candle relight? Why? What is the general nature of this smoke? How is it related to the candle wax? How does (*b*) contribute to the explanation of (*a*)?

(*c*) Press a piece of stiff white paper for an instant down upon the candle flame almost to the wick. Repeat several times with different parts of the paper. What does the paper show about the structure of the flame?

(*d*) Stand a lamp chimney over the lighted candle. How is the flame effected? Hold the chimney a short distance (1 centimeter or .5 inch) above the block. Does the candle continue to burn? Why? Keep the chimney in the same position and cover the top with a block of wood. What is the result? Why?

(*e*) Roll one end of the copper wire around a lead pencil to form a spiral about (2 centimeters or 1 inch) long. Press the spiral down upon the candle flame. What is the result? Why?

EXERCISES:

(1) Draw a candle flame, showing the parts.

(2) What is the essential difference between a candle flame and a Bunsen flame?

(3) Is there any essential difference between a candle flame and a gas or a lamp flame?

(4) Why do candles and lamps often smoke?

Experiment 78. — Kindling Temperature.

(*a*) Press a wire gauze down upon a Bunsen flame. Where is the flame? Hold a lighted match just above the gauze. Now where is the flame?

(*b*) Extinguish the flame. Turn on the gas, hold the gauze in the escaping gas, about 5 centimeters (2 inches) above the top of the burner, and thrust a lighted match into the gas above the gauze. Where is the flame? Lower the gauze slowly and describe the final result.

(*c*) Hold the gauze in the flame in one position for a minute or two. Where is the flame at the end of this time? Why?

EXERCISES:

(1) Define kindling temperature.

(2) What application is made of the principle illustrated by this experiment?

(3) State exactly how this experiment illustrates kindling temperature.

Experiment 79. — Reduction and Oxidation with the Blowpipe. *Materials:* Blowpipe, blowpipe tube, charcoal, lead oxide (litharge), sodium carbonate, sodium sulphate, wood charcoal, silver coin, zinc, lead, tin.

Slip the blowpipe tube into the burner, light the gas and lower the flame until it is about 4 centimeters (1.5 inches) high. Rest the tip of the blowpipe on the top of the tube, placing the tip just within the flame. Put the other end of the blowpipe between the lips, puff out the cheeks, inhale through the nose, and exhale into the tube, using the cheeks somewhat as a bellows. Do not blow in puffs, but produce a continuous flow of air by steady and easy inhaling and exhaling. The operation is natural and simple, and, if properly performed, will not make one out of breath. The flame should be an inner blue cone surrounded by an outer and almost invisible cone, though its shape varies with the method of production (see Fig. 44). Practice until the flame is produced voluntarily and without exhaustion. Watch the flame and learn to distinguish the two parts, so that they may be intelligently utilized.

I. *Reduction.* (*a*) Make a shallow hole at one end of the flat side of a piece of charcoal. Fill the hole with a mixture of equal parts of powdered sodium carbonate and lead oxide, and heat the mixture in the reducing flame. The sodium carbonate melts and assists the fusion of the oxide, but the former is not changed chemically. In a short time bright, silvery globules will appear on the charcoal. Let the mass cool, and pick out the largest globules. Put one or two in a mortar, and strike with a pestle. Are they soft and malleable, or brittle and hard? State the result when a globule is drawn across or rubbed upon a white paper. How do the properties compare with those of metallic lead? What has become of the oxygen? Of what chemical use is the charcoal?

(*b*) Grind together in a mortar a little sodium sulphate and wood charcoal, adding at intervals just enough water to hold the mass together. Heat this paste for a few minutes in the reducing flame as in (*a*). Scrape the fused mass into a test tube, boil in a little water, and put a drop of the solution on a bright silver coin. If a dark brown stain is produced, it is evidence of the formation of silver sulphide. Repeat, if no such stain is produced. State all the chemical changes which led to the production of the silver sulphide, explaining at the same time how the experiment illustrates reduction.

II. *Oxidation.* (*a*) Heat a small piece of zinc on charcoal in the oxidizing flame. What is the product? Observe its color, and the color of the coating on the charcoal when hot and cold. Record as described in (*d*).

(*b*) Heat a piece of lead as in (*a*). Observe the presence or absence of fumes, as well as the color of the coating when hot and cold. See (*d*).

(*c*) Heat a small piece of tin in the oxidizing flame. Observe as in (*b*).

(*d*) Tabulate the above observations, stating (1) the color of the hot and cold coating on the charcoal, (2) presence or absence of fumes, (3) name of product.

Exercises:

(1) Sketch a blowpipe.

(2) Sketch a flame showing the oxidizing and reducing parts.

FLUORINE, BROMINE, AND IODINE.

Experiment 80. — Preparation and Properties of Hydrofluoric Acid. *Materials:* Lead dish, glass plate, paraffin, file, calcium fluoride, concentrated sulphuric acid.

Precaution. *Hydrofluoric acid gas is a corrosive poison. An aqueous solution of the gas — commercial hydrofluoric acid — burns the flesh frightfully.*

Warm a glass plate about 10 centimeters (4 inches) square by dipping it into hot water or by standing it near a warm object, such as a radiator. If it is held over a flame, it is liable to crack. Coat one surface with paraffin. The surface should be uniformly covered with a thin layer. Scratch letters, figures, or a diagram through the wax with a file. Be sure the instrument removes the wax through to the glass, and that the lines are not too fine.

Put 5 grams of calcium fluoride in a lead dish and add just enough concentrated sulphuric acid to form a thin paste. Stir the mixture with a file. Place the glass plate, wax side down, upon the lead dish and stand the whole apparatus in the hood for several hours, or until some convenient time. Remove the plate. Scrape the contents of the dish, immediately, into a waste jar in the hood, and wash the dish free from acid. Most of the wax can be scraped from the glass plate with a knife. The last portions can be removed by rubbing with a cloth moistened with alcohol or turpentine. Do not attempt to melt off the wax over the flame. If the experiment has been properly performed, the plate will be etched where the glass was exposed to the hydrofluoric acid gas.

Experiment 81. — Preparation and Properties of Bromine. *Materials:* Potassium bromide, manganese dioxide, dilute sulphuric acid, bottle of water, test-tube holder. The *apparatus* is shown in Figure 111. The large test tube is provided with a one-hole rubber stopper to which is fitted the bent glass tube. The latter is about 30 centimeters (12 inches) long, and is bent according to the directions given in the Introduction, § 3 (*b*).

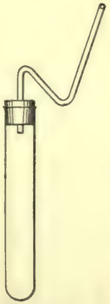

FIG. 111. — Apparatus for preparing bromine.

Precaution. *Bromine is a corrosive liquid which forms, at the ordinary temperature, a suffocating vapor. Perform in the hood all experiments which use or evolve bromine.*

Put a dozen crystals of potassium bromide in the test tube, add an equal quantity of manganese dioxide and 10 cubic centimeters of dilute sulphuric acid. Insert the stopper and its tube securely, and boil gently. Do not hold the test tube in the hand, but use the test tube holder. Brown fumes soon appear in the test tube and pass out of the delivery tube. Regulate the heating so that this vapor will condense and collect in the lower bend of the delivery tube. Both vapor and liquid are bromine. When no further boiling produces bromine vapor in the test tube, pour the bromine from the delivery tube into a bottle of water. Observe and record the physical properties of this bromine, especially the color, solubility in water, specific gravity, volatility, and physical state. Try the action of the contents of the bottle on litmus paper; if the action is not marked, push the paper down near the bromine. Determine the odor by smelling *cautiously* of the water in the bottle. As soon as these observations have been made, pour the contents of the bottle into the sink and flush with water, or pour into a jar in the hood. Wash the test tube free from all traces of bromine, taking care to get none on the hands.

ANSWER:

(1) In what ways does bromine physically resemble chlorine? In what ways does it differ from chlorine?

(2) How is it essentially different from all other elements previously studied?

Experiment 82. — Properties of Potassium Bromide. *Materials:* Potassium bromide, silver nitrate solution, ammonium hydroxide.

Examine a crystal of potassium bromide, and state its most obvious properties. Dissolve it in a test tube half full of water, and add a few drops of silver nitrate solution. Describe the result. Is the solid product soluble in ammonium hydroxide? How can bromides be distinguished from chlorides? Do the properties of bromides, typified by potassium bromide, suggest any marked relation to chlorides?

Experiment 83. — Preparation and Properties of Iodine. *Materials:* Potassium iodide, manganese dioxide, mortar and pestle, concentrated sulphuric acid, funnel, cotton.

Grind together in a mortar a dozen large crystals of potassium iodide and about twice the bulk of manganese dioxide. Put the mixture in a test tube provided with a holder, moisten with water, and add a few cubic centimeters of concentrated sulphuric acid. Plug with cotton the inside opening of a funnel, and hold the latter firmly over the mouth of the test tube. Heat the test tube gently with a low flame (5 centimeters or 2 inches). The vapor of iodine will fill the test tube, and crystals will collect in the upper part of the test tube and in the funnel. If the crystals collect in the test tube, a gentle heat will force them into the funnel. Continue to heat until enough iodine collects in the funnel for several experiments. Scrape the crystals into a dish.

Study the properties as follows: —

(*a*) Observe and record the physical properties of iodine, especially the color of the solid and of the vapor, volatility, and odor (cautiously).

(*b*) Heat a crystal in a dry test tube, and when the tube is half full of vapor, invert it. What does the result show about the density of iodine vapor?

(*c*) Touch a crystal with the finger. What color is the stain? Will water remove it? Will alcohol? Will a solution of potassium iodide? What do these results show about the solubility of iodine?

(NOTE. — If crystals are left, use them in the next experiment. Preserve in a stoppered bottle.)

Experiment 84. — Test for Iodine with Carbon Disulphide. *Materials:* Iodine, potassium iodide, carbon disulphide, chlorine water.

Precaution. *Carbon disulphide is inflammable. It should not be used near flames.*

(*a*) *Free iodine.* Add a few drops of carbon disulphide to a very dilute solution of iodine, made by dissolving a crystal of iodine in a solution of potassium iodide, and observe the color of the carbon disulphide, which, being much heavier than water, will sink to the bottom of the test tube. How does it resemble the color of iodine vapor?

(*b*) *Combined iodine.* Add a few drops of carbon disulphide to a very dilute solution of potassium iodide. Is there positive evidence of iodine? Now add several drops of chlorine water, and shake. How does this result compare with the final result in (*a*)? The result is due to the fact that chlorine liberates iodine from its compounds, and the iodine, being free, exhibits the characteristic color.

Experiment 85. — Test for Iodine with Starch. *Materials:* Starch, mortar and pestle, iodine solution, potassium iodide, chlorine water.

Grind a lump of starch in a mortar with a little water to creamy consistency. Pour this into about 100 cubic centimeters of boiling water, and stir the hot liquid. Allow it to cool, or cool it by holding the vessel in a stream of cold water, and then pour off the clear liquid. Use this cold starch solution to test for iodine.

(*a*) *Free iodine.* Add a few cubic centimeters of the starch solution to a test tube nearly full of water, and then add a few drops of iodine solution. The deep blue color is due to the presence of a compound which is always formed under these circumstances, but the composition of which is unknown. If the color is black, pour out half of the liquid and add more water, or pour some of the liquid into a dish of water.

(*b*) *Combined iodine.* Add a few cubic centimeters of the starch solution to a very dilute solution of potassium iodide. Is the blue compound formed ? Add a few drops of chlorine water, and shake. Compare with the final result in Experiment 84 (*b*).

Experiment 86. — Detection of Starch by Iodine. *Materials:* Dilute solution of iodine (in potassium iodide), mortar and pestle, potato, rice, bread.

Test the potato, rice, and bread for starch by grinding a little of each with water in a mortar, and then adding a few drops of the extract to a very dilute solution of iodine. State the result in each case.

Experiment 87. — Properties of Potassium Iodide. *Materials:* Potassium iodide, silver nitrate solution, ammonium hydroxide.

Proceed with the potassium iodide as in Experiment 82.

How can iodides be distinguished from chlorides ? Do iodides, typified by potassium iodide, suggest any marked relation to bromides and chlorides ?

SULPHUR AND ITS COMPOUNDS.

Experiment 88. — Properties of Sulphur.

(*a*) Examine a lump of sulphur, and state briefly its most obvious physical properties.

(*b*) *Optional.* Weigh a lump of roll sulphur to a decigram. Slip it carefully into a graduated cylinder previously filled with water to a known point — about half full — and note the increase in the volume of water. This increase in volume is equal to the volume of the sulphur. Calculate the specific gravity of sulphur from the observed data.

(NOTE. — Specific gravity equals weight in air divided by weight of equal volume of water.)

Experiment 89. — Amorphous Sulphur. *Materials:* Sulphur, old test tube, evaporating dish.

Put a few pieces of roll sulphur in an old test tube. Heat carefully until the sulphur boils, and then quickly pour the contents of the test tube into a dish of cold water. This is amorphous sulphur. Note its properties. Preserve, and examine it after twenty-four hours. Describe the change, if any.

Define amorphous, and illustrate it by this experiment.

Experiment 90. — Crystallized Sulphur.[1] *Materials:* Sulphur (roll and flowers), Hessian crucible, carbon disulphide, evaporating dish.

(*a*) *Monoclinic.* Fill a small Hessian crucible nearly full of roll sulphur. Support the crucible in the ring of an iron stand, and heat until all the sulphur is melted. Let it cool, and as soon as crystals shoot out from the walls just below the surface, pour the remaining melted sulphur into a dish of cold water. When the crucible can be handled without discomfort, crack it open lengthwise. Observe and record the properties of the crystals, especially the shape, size, color, luster, brittleness, and any other characteristic property. Allow the best crystals to remain undisturbed for a day or two; then examine again, and record any marked changes.

(*b*) *Orthorhombic.* Put 3 grams of flowers of sulphur in a test tube and add about 5 cubic centimeters of carbon disulphide — remember the **precaution** to be observed in using this liquid (see Exp. 84). Shake until all the sulphur is dissolved, then pour the clear solution into an evaporating dish to crystallize. It is advisable, though not absolutely necessary, to stand the dish in the hood or out of doors, where there is no flame and where the offensive vapor will be quickly removed. Watch the crystallization toward the end, and, if perfect crystals form, remove them with the forceps (see Fig. 49). Allow the liquid to evaporate almost entirely, then remove and dry the crystals. Examine them as in (*a*) and record their properties.

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[1] See Appendix, § 3 (3), (5).

Exercises:

(1) Tabulate the essential results in (*a*) and (*b*).

(2) Make an outline sketch of an orthorhombic crystal of sulphur.

Experiment 91. — Combining Power of Sulphur. *Materials:* Sulphur, deflagrating spoon, bottle, iron powder, hydrochloric acid.

(*a*) Set fire to a little sulphur in a deflagrating spoon, and lower the spoon into a bottle. *Cautiously* waft the fumes toward the nose, and observe and describe the odor. The product is a mixture of two oxides of sulphur. What does their formation show about the combining power of sulphur?

(*b*) Repeat Experiment 34.

Results similar to that in (*b*) are obtained with copper and other metals. Draw a general conclusion regarding the power of sulphur to combine with metals.

Experiment 92. — Sulphur and Matches.

(*a*) Examine a sulphur match. Do you detect any sulphur? Where?

(*b*) Light a sulphur match, and observe the entire action, as far as the sulphur is concerned. Describe it.

(*c*) What is the function of the sulphur in a burning match?

Experiment 93. — Preparation of Hydrogen Sulphide. *Materials:* Ferrous sulphide, dilute hydrochloric acid, three bottles, three glass plates, stoppered bottle, litmus paper. Use the same *apparatus* as in Experiment 38.

Precaution. *Hydrogen sulphide is a poisonous gas and has an offensive odor. It should not be inhaled. Perform in the hood all experiments evolving hydrogen sulphide.*

(*a*) Construct and arrange an apparatus like that shown in Figure 104. Fill the test tube, *A*, one third full of coarsely powdered ferrous sulphide, insert the stopper tightly, pour enough hydrochloric acid through the safety tube to cover the contents of the test tube. Hydrogen sulphide gas is rapidly evolved. If the evolution of gas slackens or stops, warm gently or add more hydrochloric acid. Collect three bottles, removing each as soon as full and covering with a glass plate. Set aside until needed.

(*b*) As soon as the last bottle of gas has been removed and covered, put in its place a bottle one fourth full of water. Adjust its height (by wooden blocks or by lowering the generator) so that the end of the delivery tube reaches to the bottom of the bottle. Continue to pass the gas into the water, by heating the test tube if necessary. The gas will be absorbed by the water, forming **hydrogen sulphide water.** Preserve it in a stoppered bottle for Experiment 95.

Proceed at once with next experiment.

Experiment 94. — Properties of Hydrogen Sulphide Gas.

Study as follows the hydrogen sulphide gas prepared in Experiment 93: —

(*a*) Waft a *little* of the gas cautiously toward the nose, and describe the odor. This is characteristic of hydrogen sulphide, and is a decisive test. Has the gas color?

(*b*) Test the gas from the same bottle with both kinds of moist litmus paper. Is it acid, alkaline, or neutral?

(*c*) Bring a lighted match to the mouth of the same bottle. Observe the properties of the flame as in previous experiments. Observe cautiously the odor of the product of the burned gas; to what compound is the odor due? What, then, is *one* component of hydrogen sulphide?

(*d*) Burn another bottle of hydrogen sulphide and hold a cold bottle over the burning gas. What additional experimental evidence does this result give regarding the composition of hydrogen sulphide?

(*e*) Repeat any of the above with the remaining bottle of gas.

EXERCISES:

(1) Summarize the properties of hydrogen sulphide gas.

(2) State the experimental evidence of its composition.

Experiment 95. — Preparations and Properties of some Sulphides. *Materials:* Hydrogen sulphide water prepared in Experiment 93, clean copper wire, clean sheet lead, bright silver coin, lead oxide (litharge); solutions of lead nitrate, arsenic trioxide (in hydrochloric acid), tartar emetic, zinc sulphate.

(*a*) Shake the bottle of hydrogen sulphide water prepared in Experiment 93 (or a similar solution), and hold successively at the mouth or in the neck of the bottle (1) a clean copper wire, (2) a bright strip of lead, and (3) an untarnished silver coin. Describe the result in each case. These compounds are sulphides of the respective metals, (*b*) Put a little litharge — the brownish yellow oxide of lead — in a test tube, cover it with hydrogen sulphide water, and warm gently. The product is lead sulphide. Describe it. Explain the change.

(*c*) Add hydrogen sulphide water to lead nitrate solution. The product is lead sulphide. Observe the color.

(*d*) Proceed as in (*c*) with the arsenic solution. Observe the color of the arsenic sulphide.

(*e*) Proceed as in (*c*) with the tartar emetic solution. Tartar emetic is a compound of antimony. Observe the color of the antimony sulphide.

(*f*) Proceed as in (*c*) with the zinc sulphate solution. Observe the color of the zinc sulphide.

Experiment 96. — Preparation of Sulphur Dioxide. *Materials:* Sodium sulphite, concentrated sulphuric acid, litmus paper, three bottles, two glass plates, stick of wood, pink flower. The *apparatus* is constructed, arranged, and used as in Experiment 41, with one exception. The safety tube must be replaced by a dropping tube made thus: Cut off the top of a thistle tube about 2.5 centimeters (1 inch) below the juncture of the stem and cup, slip a short rubber tube (5 centimeters, 2 inches, long) over one end of the stem, attach a Mohr's pinchcock to the rubber tube, and connect the tube with the cup.

. (*a*) Put about 10 grams of sodium sulphite in the large test tube, cover with water, and insert the stopper with its tubes. Adjust the apparatus as shown in Figure 104. Fill the cup with concentrated sulphuric acid, open the pinchcock a little, and let the acid flow *drop by drop* upon the sodium sulphide. Sulphur dioxide gas is evolved and passes into the bottle, which should be removed when full, as previously described. Moist blue litmus paper held at the mouth of the bottle will show when the latter is full. Collect two bottles of gas, cover each with a glass plate, and set aside until needed.

(*b*) As soon as the second bottle of gas has been removed and covered, put in its place a bottle one fourth full of water. Adjust its height (if necessary) by wooden blocks, so that the end of the delivery tube is just above the surface. Continue to add the acid *drop by drop*, at intervals, and the gas will be absorbed by the water. Shake the bottle occasionally.

Meanwhile study the gas already collected.

Experiment 97.— Properties of Sulphur Dioxide Gas.

Proceed as follows with the gas prepared in Experiment 96 (*a*) : —

(*a*) Observe and state the most obvious physical properties, *e.g.* color, odor (cautiously), density.

(*b*) Hold a blazing stick in a bottle of the gas. Will the gas burn or support combustion? What previously acquired facts would have enabled you to predict this result?

(*c*) Pour water into the same bottle of sulphur dioxide until half full, cover with the hand, and shake. What is the evidence of solution? Is the resulting liquid acid, alkaline, or neutral?

(*d*) Moisten a pink flower with a few drops of water, hang it in the remaining bottle of sulphur dioxide, holding it in place by putting the stem between the glass and a cork. Observe and describe any change in the color of the flower. What is this operation called?

Experiment 98.— Properties of Sulphurous Acid.

Test as follows the solution of sulphurous acid prepared in Experiment 96 (*b*) : —

(*a*) Taste *cautiously*, and describe the result.

(*b*) Apply the litmus test, and state the result.

(*c*) Pour a few drops of concentrated sulphuric acid into the bottle. What gas is liberated?

Experiment 99.— Action of Sulphuric Acid with Organic Matter. *Materials:* Concentrated sulphuric acid, sheet of white paper, sugar, starch, stick of wood.

(*a*) Write some letters or figures with dilute sulphuric acid on a sheet of white paper, and move the paper back and forth over a low flame, taking care not to set fire to the paper. As the water evaporates the dilute acid becomes concentrated. Observe and describe the result. Paper is largely a compound of carbon, hydrogen, and oxygen, and the hydrogen and oxygen are present in the proportion to form water. Explain the general chemical change in this experiment.

(*b*) Fill a test tube one fourth full of sugar, add an equal bulk of water, stand the test tube in the rack, and add *cautiously* several drops of concentrated sulphuric acid. If there is no decided result, add more acid. What is the black product? Compare the final result with that obtained in Experiment 59 (*b*). Is the chemical action the same in each experiment? Are the statements made in (*a*) about paper also true of sugar?

(*c*) Repeat (*b*), using powdered starch instead of sugar. Describe the result. How does the result resemble that in (*b*) and in Experiment 59 (*a*)? Predict the components of starch. In what simple way may the prediction be verified?

(*d*) Stand a stick of wood in a test tube one fourth full of concentrated sulphuric acid. Allow it to remain in the acid for fifteen minutes, then remove the stick and wash off the acid. Describe the change in the stick. Does it resemble that in (*a*), (*b*), and (*c*), and in Experiment 59 (*a*)?

Experiment 100. — Test for Sulphuric Acid and Sulphates. *Materials:* Sulphuric acid, sodium sulphate, barium chloride solution, calcium sulphate, charcoal, powdered charcoal, blowpipe, silver coin.

(*a*) Repeat Experiment 12 (*c*) with sulphuric acid and with sodium sulphate solution.

(*b*) Repeat Experiment 79 I (*b*) with calcium sulphate instead of sodium sulphate.

EXERCISES:

(1) State briefly the test for sulphuric acid and soluble sulphates. For insoluble sulphates.

(2) How can a sulphate be distinguished from a sulphite?

SILICON AND BORON.

Experiment 101. — Preparation and Properties of Silicic Acid. *Materials:* Sodium silicate solution, hydrochloric acid, evaporating dish, gauze-covered ring.

Add dilute hydrochloric acid to a test tube half full of sodium silicate solution, and shake. The jellylike precipitate is silicic acid. Rub some between the fingers and describe the result. Evaporate the precipitate to dryness in a porcelain dish which stands upon a gauze-covered ring in the hood. As the mass hardens, stir it with a glass rod. Toward the end, add more hydrochloric acid and evaporate to complete dryness. Then heat strongly for five minutes. The residue is silicon dioxide mixed with chlorides of sodium and potassium. Rub some between the fingers or across a glass plate. Is any grit detected? State the chemical changes which occur in changing sodium silicate into silicon dioxide.

Experiment 102. — Tests with Borax Beads. *Materials:* Powdered borax, platinum test wire (see Int. § 5 (4)), solutions of cobalt nitrate and copper sulphate, manganese dioxide.

Make a small loop on the end of the platinum test wire, moisten it, and dip it into powdered borax. Heat it in the flame, rotating it slowly; at first the borax swells, but finally shrinks to a small, transparent bead. If the bead is too small add more borax and heat again. After use, the bead may be removed by dipping it, white hot, into water; the sudden cooling shatters the bead, which may then be easily rubbed or scraped from the wire.

(*a*) *Cobalt Compounds.* Touch a transparent borax bead with a glass rod which has a drop of cobalt nitrate solution on the end. Heat the bead in the oxidizing flame. Observe the color when cold. If it is black melt a little more borax into the bead; if faintly colored, moisten again with the cobalt solution. The color is readily detected by looking at the bead against a white object in a strong light, or by examining it with a lens. When the color has been definitely determined, heat again in the reducing flame. Compare the color of the cold bead with the previous observation.

(*b*) *Copper compounds.* Make another transparent bead, moisten it with copper sulphate solution and heat it first in the oxidizing flame, and then in the reducing flame. Compare the colors of the cold beads, and draw a conclusion.

(*c*) *Manganese Compounds.* Make another transparent bead, touch it with a minute quantity of manganese dioxide, and proceed as in (*b*). Compare the colors of the cold beads, and draw a conclusion.

(*d*) Tabulate the results of this experiment.

EXERCISE:

Draw a Bunsen flame, showing the reducing and oxidizing parts.

Experiment 103. — Preparation and Properties of Boric Acid and the Test for Boron. *Materials:* Borax, alcohol, evaporating dish, concentrated hydrochloric acid.

To a test tube half full of boiling water, add about 10 grams of powdered borax. Add about 5 cubic centimeters of concentrated hydrochloric acid to this hot solution, and let the whole cool. Crystals of boric acid will separate. Filter. Describe the crystals.

Put some of the crystals in an evaporating dish, add a little alcohol, and set fire to the solution. Observe the color of the flame. It is caused by a complex compound of boron, and is the test for this element.

PHOSPHORUS, ARSENIC, ANTIMONY, AND BISMUTH.

Experiment 104. — Some Properties of Phosphorus.

(*a*) Smell of the head of a phosphorus-tipped match. Describe the odor.

(*b*) Rub the head of a phosphorus-tipped match in a dark place, and observe and describe the result.

(*c*) The most striking property of phosphorus is the readiness with which it lights and burns in air. This property is too dangerous to try in the laboratory. Read about it in the text book. What application is made of this property? Why?

Experiment 105. — Test for Arsenic.

Repeat Experiment 95 (*d*).

Experiment 106. — Test for Antimony.

Repeat Experiment 95 (*e*).

Experiment 107. — Test for Bismuth. *Materials:* Bismuth, *aqua regia.*

Prepare a solution of bismuth chloride by heating the metal with *aqua regia.* Fill the test tube half full of water, and describe the result. The product is bismuth oxychloride. How is it related to bismuth chloride?

SODIUM.

Experiment 108. — Properties of Sodium. *Materials:* Sodium, pneumatic trough filled with water as usual, litmus paper, filter paper, tea lead.

Precaution. *Observe the precautions as in Experiment 24.*

(*a*) Examine a small piece of sodium, and record its most obvious physical properties, *e.g.* color, luster, whether hard or soft, etc.

(*b*) Repeat Experiment 24 (except (*e*)).

ANSWER:

(1) Is sodium heavier or lighter than water?

(2) What properties show that it is a metal?

(3) Is it harder or softer than most metals?
(4) What is the test for sodium?

Experiment 109.—Preparation and Properties of Sodium Hydroxide. *Materials:* Sodium carbonate, lime, zinc sulphate solution, iron (or tin) dish, file.

Dissolve 25 grams of sodium carbonate in 150 cubic centimeters of water and heat gently in an iron dish (an ordinary iron spider is well adapted for this work). Meanwhile slake 10 grams of lime by adding just enough water to make a milky liquid — "milk of lime." Add the milk of lime to the sodium carbonate solution and boil for several minutes, stirring constantly with a file. Let the precipitate settle, remove a little liquid with a small tube, and if it effervesces with hydrochloric acid, add more milk of lime and boil; if not, pour the liquid into a convenient vessel, let it stand for a few minutes or until the solid settles; then pour the liquid down a glass rod (see Int. § 6 (1)) into a bottle. This solution of sodium hydroxide may be evaporated to dryness, and the solid product tested and the remainder preserved, or the solution may be tested at once as follows: —

(*a*) Rub a little between the fingers and describe the feeling.

(*b*) Apply the litmus test. Is it acid or alkaline? Is it markedly so?

(*c*) Add a little to a zinc sulphate solution, and shake. The precipitate is zinc hydroxide. Describe it. Now add an excess of sodium hydroxide, and shake. Describe the result. The excess of sodium hydroxide forms soluble sodium zincate. This behavior of zinc compounds is the **test for an hydroxide.**

(*d*) How do sodium compounds affect a colorless flame? Try it, if in doubt.

Exercises for Review.

1. How does sodium carbonate act when exposed to air? Sodium sulphate? Sodium hydroxide?

2. How does sodium carbonate solution affect litmus paper? How does its action compare with that of other salts, sodium chloride for example?

3. What marked property has sodium carbonate, and how is this property utilized?

4. How does sodium bicarbonate interact with tartaric acid? Would the action be the same with other acids?

5. "Sodium thiosulphate forms a supersaturated solution." Explain and illustrate this statement.

6. How does sodium chloride interact with sulphuric acid? Sodium nitrate with sulphuric acid?

POTASSIUM.

Experiment 110. — Properties of Potassium. *Materials:* Potassium, pneumatic trough filled as usual, litmus paper.

Precaution. *Observe the same precaution as in using sodium.*

(*a*) Examine a very small piece of freshly cut potassium, and record its most obvious physical properties. Touch it slightly. Does it suggest caustic potash and soda?

(*b*) Drop a small piece of potassium on the water in a pneumatic trough. Stand just near enough to see the action. Describe the action. How does it differ from the action of sodium? Test the water as in Experiment 24 (*d*).

From what has already been learned about sodium and potassium, predict the main chemical change observed in (*b*).

ANSWER:

(1) Is potassium heavier or lighter than water?

(2) What properties suggest that it is a metal?

(3) How does it resemble and differ from sodium?

(4) How does potassium color a flame?

(5) What is the test for potassium?

Experiment 111. — Preparation and Properties of Potassium Hydroxide. *Materials:* Potassium carbonate, lime, zinc sulphate solution, iron (or tin) dish, file.

Proceed as in Experiment 109, but use potassium carbonate instead of sodium carbonate. Test as in the case of sodium hydroxide.

Experiment 112. — Preparation and Properties of Potassium Carbonate. *Materials:* Cream of tartar, wood ashes, litmus paper, hydrochloric acid, iron sand bath pan, mortar and pestle.

(*a*) Heat strongly 5 grams of cream of tartar — acid potassium tartrate — in an iron pan in the hood until the residue is nearly white. Grind this solid with water in a mortar, and filter. Test the filtrate (1) with both kinds of litmus paper, (2) for potassium, and (3) for a carbonate. Record the results.

(*b*) Fill a test tube half full of wood ashes, add half the volume of water, shake, and warm gently. Filter, and test the filtrate as in (*a*). If test (3) is not decisive, repeat the experiment on a larger scale. Record the results.

(*c*) Expose a little potassium carbonate to the air for an hour or more. Describe the result. How does its behavior compare with that of sodium carbonate under the same conditions?

ANSWER:

(1) What is the source of cream of tartar?

(2) What do (*a*) and (*b*) show about the distribution of potassium? Of its assimilation by plants?

(3) What is the literal meaning of the word *potash?*

Exercises for Review.

1. What does potassium chlorate yield when heated?

2. Does potassium chlorate dissolve readily in cold water? In hot water?

3. What is formed by heating potassium bromide with manganese dioxide and sulphuric acid?

4. Apply question 3 to potassium iodide.

5. What happens to potassium hydroxide when exposed to air? To potassium carbonate?

6. Of what important mixture is potassium nitrate an ingredient?

COPPER.

Experiment 113. — Physical Properties of Copper.

Examine several forms of copper — wire, sheet, filings, etc. — and state the most obvious physical properties.

ANSWER:

(1) Is copper a good conductor of heat? Of electricity? On what evidence is your answer based?

(2) Is copper ductile? Malleable? Brittle? Tough? Hard or soft?

(3) What happens to copper when heated? When exposed to the air?

Experiment 114. — Tests for Copper. *Materials:* Copper wire, copper sulphate solution, ammonium hydroxide, acetic acid, potassium ferrocyanide solution.

(*a*) Heat a copper wire in the Bunsen flame. The color is characteristic of copper and its compounds, though not a conclusive test, since the same color is produced by other substances.

(*b*) Add a few drops of ammonium hydroxide to copper sulphate solution, and observe the result; now add an excess of ammonium hydroxide. The blue solution is a characteristic and decisive test for copper.

(*c*) Add to a test tube one fourth full of water an equal volume of copper sulphate solution, and shake; then add a few drops of acetic acid and of potassium ferrocyanide solution. The brown precipitate is copper ferrocyanide.

Experiment 115. — Interaction of Copper with Metals. *Materials:* Copper wire, iron nail, zinc, solutions of copper sulphate and any mercury compound.

(*a*) Put a clean copper wire into a solution of any mercury compound. After a short time, remove the wire and wipe it with a soft cloth or paper. Describe the change. What has become of some of the copper?

(*b*) Put in separate test tubes half full of copper sulphate solution a bright iron nail and a strip of clean zinc. After a short time remove the metals and examine them. What is the deposit? What has become of some of the zinc and iron? Does the final color of the solution indicate any chemical change? How would you prove the answer to the last question?

Exercises for Review.

1. What happens to a crystal of copper sulphate when heated?
2. You are given a blue solution supposed to be copper sulphate. State how you would prove it.
3. What are formed by the interaction of copper and nitric acid?
4. What color have many copper compounds?
5. "Brass is an alloy of copper." State how you would prove this.

SILVER AND GOLD.

Experiment 116. — Preparation of Silver. *Materials:* (*a*) Silver nitrate solution, mercury, evaporating dish; (*b*) ten-cent piece, concentrated nitric acid, hydrochloric acid, sulphuric acid, zinc, evaporating dish, charcoal, sodium carbonate, blowpipe.

Prepare silver by one or both of the following methods: —

(*a*) Fill a porcelain dish half full of silver nitrate solution, and add a few drops of mercury. Allow the whole to stand undisturbed for a day or more, and then examine. The delicate crystals attached to the mercury are silver. Pick them out with the forceps, wash well with water, and preserve them for Experiment 117.

(*b*) Dissolve a ten-cent piece in 10 cubic centimeters of concentrated nitric acid, dilute with an equal volume of water, and add hydrochloric acid until the precipitation is complete. Let the precipitate settle. Then filter, and wash until the filtrate is neutral. If convenient, let the precipitate dry; if not, scrape half from the opened paper with a knife, put it in a porcelain dish, cover with dilute sulphuric acid, and add a piece of zinc; put the other half in a cavity at the end of a piece of charcoal, cover with sodium carbonate, and reduce it with a blowpipe flame. In the first case, the silver will collect as a grayish powder; remove any excess of zinc, filter, wash with water and dry the residue. It may be preserved as a powder, or fused into a bead with a blowpipe flame. In the second case, minute globules of silver will appear on the charcoal; scrape them together and fuse into a single bead. Preserve it.

Experiment 117. — Properties of Silver.

Examine the silver formed in Experiment 116, and state briefly its most obvious properties.

Experiment 118. — Test for Silver.

Devise a test for combined silver, based upon previous experiments. Verify it.

Exercises for Review.

1. What is formed by the interaction of silver nitrate and potassium chloride? Potassium bromide? Potassium iodide? How do the products differ?

2. What caused the blue filtrate in Experiment 116 (*b*)? What metal besides silver does a ten-cent piece contain?

3. What compound is formed when silver tarnishes?

4. What is the test for a chloride?

Experiment 119. — Interaction of Gold and Aqua Regia and the Test for Gold. *Materials:* Gold leaf, concentrated nitric and hydrochloric acids, stannous chloride solution.

Prepare a solution of gold chloride according to Experiment 58, using as small a volume of the acids as possible. Dilute with water, and then slowly add a dilute solution of stannous chloride. A precipitate is produced, varying in color from faint purple to black according to the conditions. This precipitate is supposed to be finely divided gold, and is called *Purple of Cassius;* its formation is the test for gold.

CALCIUM.

Experiment 120. — Tests for Calcium.

(*a*) Subject calcium chloride to the flame test. Record the result.

(*b*) Repeat Experiment 12 (*d*).

Experiment 121. — The "Setting" of Plaster of Paris. *Materials:* Plaster of Paris, block of wood.

Mix a little plaster of Paris with enough water on a block of wood to form a thin paste. Let it stand undisturbed for a few minutes, and then examine. Describe the change. How is this property utilized?

Exercises for Review.

1. Describe calcium chloride. How does it act when exposed to the air? How would you show that it (*a*) contains calcium and (*b*) is a chloride?

2. Describe lime. What effect does water have upon it?

3. What compounds are produced by the interaction of calcium carbonate and hydrochloric acid?

4. What is limewater? Milk of lime?

5. What is formed when carbon dioxide is passed into limewater? Into sodium hydroxide?

6. What compounds are formed by heating calcium carbonate?

7. What happens when an excess of carbon dioxide is passed into limewater?

8. What is acid calcium carbonate? How can it be changed into normal calcium carbonate?

9. What compounds are formed by the interaction of calcium fluoride and sulphuric acid?

10. What is calcium hypochlorite? For what is it used?

11. What happens to crystallized calcium sulphate (selenite) when heated?

12. Calcium sulphate is nearly insoluble in water; how can it be shown to be a sulphate?

13. What is tricalcium phosphate? Superphosphate of lime?

14. What is the scientific name of lime, limestone, marble, gypsum, fluor spar, limewater, slaked lime, quicklime, bleaching powder, chloride of lime?

STRONTIUM.

Experiment 122. — Test for Strontium.

Dip a platinum test wire (or a glass rod) into a solution of strontium nitrate, and hold it in the Bunsen flame. Describe the result, after several trials.

Experiment 123. — Red Fire. *Materials:* Strontium nitrate, powdered potassium chlorate, powdered shellac, iron pan or brick.

Mix carefully small and equal (in bulk) quantities of the three substances on a sheet of paper. Place the mixture on a sand-bath pan or a brick in the hood, and light it with a Bunsen burner. Describe the result.

BARIUM.

(*Compounds of Barium are Poisonous.*)

Experiment 124. — Tests for Barium.

(*a*) Repeat Experiment 122, using a solution of barium chloride or barium nitrate. Be sure the test wire (or rod) is clean. Describe the result.

(*b*) Devise a test. (Suggestion. What is the test for a sulphate?)

Experiment 125. — Green Fire.

Repeat Experiment 123, using barium nitrate instead of strontium nitrate.

Exercises for Review.

1. State the properties of barium sulphate.
2. How does barium chloride behave toward litmus?
3. What industrial use have the barium oxides?

MAGNESIUM.

Experiment 126. — Properties of Magnesium.

Examine a piece of magnesium and state briefly its most obvious properties.

Experiment 127. — Tests for Magnesium. *Materials:* Solutions of magnesium sulphate (or chloride), ammonium chloride, ammonium hydroxide, disodium phosphate, and cobaltous nitrate; magnesium oxide, charcoal, blowpipe.

(*a*) To a solution of magnesium sulphate (or chloride) add successively solutions of ammonium chloride, ammonium hydroxide, and disodium phosphate. A precipitate of ammonium magnesium phosphate is formed. It is voluminous at first, but finally crystalline. It is soluble in acids. Try it.

(*b*) Put a little powdered magnesium oxide in a cavity at the end of a piece of charcoal, moisten with water, and heat intensely in a blowpipe flame. Cool, and moisten with a drop of cobaltous nitrate solution. Heat again, and when cool observe the color. If the experiment has been conducted properly, a pink or pale flesh-colored residue coats the charcoal. Describe the result.

Exercises for Review.

1. What compound is formed by burning magnesium in air or in oxygen? Describe it.
2. How was magnesium utilized in the discovery of argon?

ZINC.

Experiment 128. — Properties of Zinc.

Examine a piece of zinc and record its most obvious properties.

ANSWER:

1. What happens to zinc when it is heated? Describe and name the product.
2. Is zinc hard or soft? Malleable? Ductile? Brittle? Tough? Does it melt readily?

Experiment 129. — Tests for Zinc. *Materials:* Zinc oxide, cobaltous nitrate solution, charcoal, blowpipe.

(*a*) Recall or devise a simple test for combined zinc. (Suggestion. See Exp. 109 (*c*).)

(*b*) Recall or repeat the action of zinc when heated in the oxidizing flame. (See Exp. 79 II (*a*).)

(*c*) Fill a small cavity at one end of a piece of charcoal with zinc oxide, moisten with water, and heat strongly in the blowpipe flame. Cool, and moisten with a drop of cobaltous nitrate solution, then heat again. Cool and examine. A green incrustation is caused by zinc compounds.

Experiment 130. — Interaction of Zinc and Metals. *Materials:* Sheet zinc, solutions of copper sulphate, lead nitrate, mercurous nitrate.

(*a*) Repeat Experiment 115 (*b*).

(*b*) Repeat (*a*) using lead nitrate solution.

(*c*) Repeat (*a*) using the mercury salt solution. Examine after a short time, and describe. What is amalgamated zinc, and for what is it used?

Exercises for Review.

1. What are formed by the interaction of zinc and sulphuric acid? Of zinc and nitric acid?

2. What is formed by the interaction of a zinc salt and a little sodium hydroxide solution? An excess of the alkali?

CADMIUM.

Experiment 131. — Test for Cadmium.

Add hydrogen sulphide water to a test tube half full of cadmium chloride solution. The precipitate is cadmium sulphide. Describe it. Let it settle, pour off most of the liquid, fill the test tube half full with dilute sulphuric acid, and warm. Describe the result.

MERCURY.

(*Mercury and its Compounds are Poisonous.*)

Experiment 132. — Properties of Mercury.

(*a*) Pour a drop or two of mercury into an evaporating dish. Examine the mercury, and state its characteristic properties. Agitate the dish, and describe the result. Why is mercury called "quicksilver"?

(*b*) Lift carefully a bottle of mercury. Estimate the specific gravity. Verify the estimate by consulting a book.

Experiment 133. — Tests for Mercury.

(*a*) What is a simple test for free mercury?

(*b*) Recall or devise a test for combined mercury. Verify it. (Suggestion. See Exp. 115.)

Experiment 134. — Properties of Mercurous and Mercuric Compounds. *Materials:* Solutions of mercurous and mercuric nitrate; hydrochloric acid, ammonium hydroxide.

(*a*) *Mercurous.* Add a few drops of hydrochloric acid to a little mercurous nitrate solution. The white precipitate is mercurous chloride. Note its insolubility in water and in dilute hydrochloric acid. Add a few drops of ammonium hydroxide. The black precipitate is mercurous ammonium chloride. Its formation is a delicate test for mercury in mercurous compounds.

(*b*) *Mercuric.* Add a few drops of hydrochloric acid to a little mercuric nitrate solution. Compare the result with that in (*a*). Add a few drops of ammonium hydroxide, or enough to produce a decided change. Compare with (*a*). The precipitate is mercuric ammonium chloride.

Exercises for Review.

1. Describe the effect of heat on red oxide of mercury. What historical interest has this experiment?
2. What practical use has mercury?
3. What are amalgams?
4. What action has mercury upon gold?

ALUMINIUM.

Experiment 135. — Properties of Aluminium.

(*a*) Examine a piece of aluminium, and observe its properties. Has it any "spring" like brass? Is it ductile, malleable, soft, hard, tough, brittle? Will it melt in the Bunsen flame? Try it.

(*b*) Compare roughly the weight of a piece of sheet aluminium with a piece of pasteboard or glass having approximately the same volume. Estimate the specific gravity. Verify it by consulting a book.

Experiment 136. — Action of Aluminium with Acids and Alkalies. *Materials:* Aluminium, sulphuric acid, hydrochloric acid, sodium hydroxide solution.

(*a*) Add a small piece of aluminium to separate test tubes containing dilute sulphuric acid and concentrated hydrochloric acid. Warm, if necessary. Describe the action. Test the gas evolved. What compound is formed in each case?

(*b*) Add a small piece of aluminium to a test tube half full of dilute sodium hydroxide solution, and boil. Test any gas evolved. If only a little gas is liberated, attach a simple delivery tube and collect the gas over water.

Other acids and alkalies act similarly. Draw a general conclusion from this experiment.

Experiment 137. — Preparation and Properties of Aluminium Hydroxide. *Materials:* Solutions of alum, sodium hydroxide, ammonium sulphide, and cochineal; hydrochloric acid and ammonium hydroxide.

(*a*) Add slowly a little sodium hydroxide solution to a test tube half full of alum solution. The gelatinous precipitate is aluminium hydroxide. Now add an excess of the alkali to one half, and dilute hydrochloric acid to the other. Describe the results.

(*b*) Add a little solution of ammonium sulphide to a solution of alum. Describe the result. The precipitate is not a sulphide, but aluminium hydroxide, because aluminium forms no sulphide in the wet way.

(*c*) Add a little alum solution to a dilute solution of cochineal, then add ammonium hydroxide. The colored product is called carmine lake. It belongs to a class of dyes formed by the combination of a vegetable dye and a metallic hydroxide, often aluminium hydroxide.

Experiment 138. — Tests for Aluminium. *Materials for* (*c*)*:* Aluminium sulphate; cobaltous nitrate solution, blowpipe, charcoal.

(*a*) What is a simple test for metallic aluminium?

(*b*) Recall or devise a test for combined aluminium. Verify it. How can aluminium compounds be distinguished from those of zinc?

(*c*) Heat a little aluminium sulphate on charcoal in the blowpipe flame. Cool, and moisten with a drop of cobaltous nitrate solution. Heat again, and if the operation has been conducted properly, a blue residue will coat the charcoal. This color is characteristic of aluminium compounds. Compare this result with the action of other metallic compounds under similar circumstances.

Experiment 139. — Preparation and Properties of Common Alum. *Materials for (a):* Aluminium sulphate, potassium sulphate, evaporating dish.

(*a*) Dissolve about 10 grams of aluminium sulphate in the least possible amount of hot water. Dissolve 3 grams of potassium sulphate in the same way. Mix the clear, hot, saturated solutions in an evaporating dish, and allow the solution to cool undisturbed. Crystals of potassium alum will be deposited. Remove the best ones; dry and examine. Describe them, giving color, luster, size, and crystal form.

(*b*) Prove by actual tests that (1) they are a sulphate, and (2) they contain aluminium and water of crystallization.

TIN.

Experiment 140. — Properties of Tin. Examine a piece of tin, and state its most obvious properties. Is it malleable, soft, hard, tough, brittle? Will it melt in the Bunsen flame? Try it.

Experiment 141. — Action of Tin with Acids. *Materials:* Tin, concentrated nitric and hydrochloric acids.

(*a*) Put a small piece of tin in a test tube, cover with concentrated hydrochloric acid, add a little water, and heat — *in the hood.* Heat gently at first, and when action begins regulate the heat accordingly. Most of the tin disappears, soluble stannous chloride being formed. Save this solution for Experiment 142.

(*b*) Treat a small piece of tin with concentrated nitric acid — *in the hood.* It is advisable to stand the test tube in the rack or in a bottle as soon as the action begins. The white, amorphous product is metastannic acid. How does the action of nitric acid on tin differ from and resemble its action on other metals, zinc, for example?

Experiment 142. — Tests for Tin. *Materials for (c):* Solutions of mercuric chloride and stannous chloride.

(*a*) What is a simple test for metallic tin?

(*b*) Recall or repeat the action of tin when heated in a blowpipe flame.

(*c*) Add a few drops of mercuric chloride solution (*poison*) to a little of the stannous chloride solution prepared in Experiment 141. The white precipitate is mercurous chloride. Add a little more stannous chloride solution and heat gently. The mercurous chloride is reduced finally to mercury, which appears as a grayish powder.

Experiment 143. — Deposition of Tin.

Put a strip of zinc in a slightly acid solution of stannous chloride. Examine after a short time. The tin will be found adhering to the zinc as a grayish black deposit; sometimes bright scales are also seen. What has become of the zinc?

LEAD.

Experiment 144. — Properties of Lead.

(*a*) Examine a piece of freshly cut lead and state its most obvious physical properties.

(*b*) Estimate its specific gravity. Verify your estimate by consulting a book.

(*c*) Draw a piece of lead across a sheet of white paper, and describe the result.

(*d*) Is lead easily melted? Try it.

ANSWER:

(1) What happens to lead when exposed to the air?
(2) What properties adapt lead for its extensive use?
(3) What is "black lead"?
(4) Is there lead in a lead pencil?

Experiment 145. — Tests for Lead. *Materials for* (*c*), (*d*), (*e*): Lead nitrate and potassium dichromate solutions, sulphuric acid, hydrochloric acid.

(*a*) Recall or repeat the reduction of lead oxide in the blowpipe flame. (See Exp. 79.)

(*b*) Recall or repeat the action of hydrogen sulphide with the solution of a lead compound. (See Exp. 95 (*c*).)

(*c*) Add dilute hydrochloric acid to a little lead nitrate solution until precipitation ceases. Note the insolubility of the lead chloride which is formed. Warm gently as long as any decided change occurs. Describe the action. This is characteristic of lead chloride and permits its separation from the chlorides of silver and of mercury (in the *-ous* condition).

(*d*) Add dilute sulphuric acid to a little lead nitrate solution until precipitation ceases. The precipitate is lead sulphate. Observe its properties. Is it soluble in hot water? Try it.

(*e*) Repeat (*d*), using potassium dichromate solution instead of sulphuric acid. The precipitate is lead chromate. Describe it, especially the color.

Experiment 146. — Deposition of Lead.

Repeat Experiment 130 (*b*).

Experiment 147. — Properties of Lead Oxides. *Materials:* Lead monoxide, dioxide, and tetroxide, nitric acid.

(*a*) Examine the three oxides and tabulate their most obvious physical properties, stating the exact chemical name and formula and the popular name of each oxide.

(*b*) Recall the experiment in which lead was heated in the oxidizing flame, especially the color of the coating. What oxide of lead is thereby formed?

(*c*) Warm a little lead tetroxide with dilute nitric acid. The solid product is lead dioxide. Describe it.

EXERCISES:

(1) How might lead tetroxide be prepared?

(2) If lead tetroxide is heated strongly, lead monoxide is formed. What does this fact reveal about the stability of lead tetroxide?

(3) When lead dioxide and concentrated hydrochloric acid are mixed and heated, chlorine is evolved. Complete the equation —

$$PbO_2 + 4\,HCl = PbCl_2 + 2\,H_2O +$$

How does this interaction resemble that of manganese dioxide and hydrochloric acid?

Experiment 148. — Properties of Certain Lead Compounds. *Materials:* Lead nitrate, lead carbonate, galena, taper, mortar and pestle.

(*a*) Put a crystal of lead nitrate in a test tube provided with a holder, hold in a horizontal position, and heat strongly in the upper part of the Bunsen flame. Describe the result. What is the most obvious product? After most of this product has passed out of the test tube, thrust well into the test tube a taper with a spark on the end. Describe the result. What other gas is present? The solid product is lead monoxide. Summarize the behavior of lead nitrate when heated.

(*b*) Examine lead carbonate, and state its most obvious properties. What is its common name? Prove that it is a carbonate and contains lead. (Suggestion. Treat with hydrochloric acid.)

(*c*) Examine a lump of galena, and state its most obvious properties. Pulverize it in a mortar. What additional property is revealed? Prove that it is a sulphide and contains lead. (Suggestion. See Exps. 93 and 145.)

CHROMIUM.

Experiment 149. — Tests for Chromium. *Materials:* Borax, chrome alum, potassium carbonate, potassium nitrate, acetic acid, nitric acid, sodium hydroxide solution, lead nitrate solution, potassium dichromate solution, platinum test wire, piece of porcelain, forceps.

(*a*) Prepare a borax bead (see Exp. 102), touch it with a minute quantity of chrome alum, and heat in both the oxidizing and reducing flame. Describe the result.

(*b*) Mix equal small quantities of potassium carbonate, potassium nitrate, and powdered chrome alum, place the mixture on a piece of porcelain, and hold it with the forceps in the upper Bunsen flame so that the mixture will fuse. A yellow mass, due to the presence of potassium chromate, results. If the color is not decided, dissolve the mass in water, add acetic acid, slowly at first, and boil to expel the carbon dioxide. Add a few drops of lead nitrate solution to a portion, and yellow lead chromate is precipitated. If the precipitate is white, it is lead carbonate, and shows that not all the potassium carbonate was decomposed, as intended.

(*c*) Add lead nitrate solution to potassium dichromate solution. Name and describe the precipitate. Try the solubility of the precipitate in acetic acid, dilute nitric acid, and sodium hydroxide. Describe the result.

Experiment 150. — Properties of Chromates. *Materials:* Potassium chromate and dichromate, concentrated hydrochloric acid, potassium hydroxide solution.

(*a*) Examine crystals of potassium chromate and dichromate, and state their characteristic properties. Make a dilute solution of each, and compare the colors. Save for (*c*) and (*d*).

(*b*) State the properties of lead chromate.

(*c*) Add a few drops of concentrated hydrochloric acid to the solution of potassium chromate prepared in (*a*), and observe the change in color. Describe it. Compare with the color of the potassium dichromate solution prepared in (*a*). Draw a conclusion.

(*d*) Add potassium hydroxide solution to the solution of potassium dichromate prepared in (*a*) until a change of color is produced. Describe the color. Compare with the potassium chromate solution. Draw a conclusion.

(*e*) The chromates are oxidizing agents. Add a few drops of concentrated hydrochloric acid to powdered potassium chromate and dichromate in separate test tubes. Chlorine is evolved. Where did it come from? By what general chemical change?

Experiment 151. — Reduction of Chromates to Chromic Compounds. *Materials:* Potassium dichromate solution, concentrated hydrochloric acid, alcohol.

Add to a few cubic centimeters of potassium dichromate solution a little concentrated hydrochloric acid and a few drops of alcohol. Warm gently. Two important changes occur. The chromate is *reduced* to chromic chloride which colors the solution green; the alcohol is oxidized to aldehyde, which is detected by its peculiar odor.

Experiment 152. — Preparation and Properties of Chromic Hydroxide. *Materials:* Ammonium sulphide, solutions of sodium hydroxide and chrome alum.

(*a*) Add a little sodium hydroxide solution to a solution of chrome alum. The precipitate is chromic hydroxide. Describe it. Add an excess of sodium hydroxide solution, and shake. Describe the result. Boil, and state the result.

(*b*) Add a little, and then an excess, of ammonium sulphide to a solution of chrome alum. Compare the result with that in (*a*). Does chromium form a sulphide?

ANSWER:

How can chromic hydroxide be distinguished from aluminium hydroxide?

Experiment 153. — Properties of Chrome Alum.

(*a*) Examine chrome alum and state its most obvious physical properties.

(*b*) Prove that chrome alum is a sulphate, and that it contains chromium and water of crystallization.

MANGANESE.

Experiment 154. — Tests for Manganese. *Materials for* (*b*) *and* (*c*): Manganese dioxide, potassium carbonate, potassium nitrate, ammonium sulphide, manganese sulphate solution, hydrochloric acid, acetic acid, ammonium hydroxide.

(*a*) Subject a minute quantity of manganese dioxide to the borax bead test, and note the color of the bead after heating in each flame. (See Exp. 102.)

(*b*) Fuse, on a piece of porcelain, a little manganese dioxide mixed with potassium carbonate and potassium nitrate. The green mass is a test for manganese. It is due to the presence of potassium manganate.

(*c*) Add ammonium sulphide to manganese sulphate solution. The flesh-colored precipitate is manganese sulphide. Compare with other sulphides as to color (see Exp. 95). Divide it into two parts. Add hydrochloric acid to one, and acetic acid to the other, then add an excess of ammonium hydroxide to each. Draw a conclusion regarding the solubility of manganese sulphide.

Experiment 155. — Oxidation with Potassium Permanganate. *Materials:* Potassium permanganate, sulphuric acid, ferrous sulphate, filter paper.

(*a*) Add a few drops of sulphuric acid to a weak solution of *fresh* ferrous sulphate; then add, drop by drop, a dilute solution of potassium permanganate. Its color is changed, owing to the loss of oxygen; the latter converts the ferrous to ferric sulphate. The decomposition of the permanganate also causes the formation of potassium and manganese sulphates.

(*b*) Pour a solution of potassium permanganate upon a piece of filter paper. Describe and explain the result.

Exercises for Review.

1. Describe manganese dioxide. Name five elements in whose preparation manganese dioxide is used. Is manganese dioxide an oxidizing agent?

2. Describe potassium permanganate. What can be said of its solubility in water? In what previous experiment has it been used?

3. What is the formula of potassium permanganate? Does the formula suggest its oxidizing power?

IRON.

Experiment 156. — Properties of Iron. *Materials:* Cast and wrought iron, steel, magnet, iron wire, iron powder.

(*a*) Examine cast iron, wrought iron, and steel, and state their most obvious physical properties.

(*b*) Try the action of a magnet on each. Describe the result.

(*c*) Drop a pinch of iron powder into the Bunsen flame. Hold a piece of fine iron wire in the flame. Describe the results, and draw a conclusion.

Experiment 157. — Properties of Ferrous Compounds. *Materials:* Iron powder (or filings), hydrochloric acid, solutions of sodium hydroxide, potassium ferricyanide, potassium thiocyanate, potassium ferrocyanide.

Put a few grams of iron powder in a test tube, add about 10 cubic centimeters of dilute hydrochloric acid, and warm gently; ferrous chloride is formed (in solution). Proceed as follows: (1) Pour a little into a test tube one third full of sodium hydroxide solution. The precipitate is ferrous hydroxide. Watch the changes in color. To what are the changes due? (2) Add a second portion to potassium ferricyanide solution. The precipitate is ferrous ferricyanide. Describe it. (3) Add a third portion to potassium thiocyanate solution. If ferric salts are absent, no change results. (4) Add a fourth portion to potassium ferrocyanide solution. The precipitate is ferrous ferrocyanide. Describe it. Tabulate the results as described in the next experiment.

Experiment 158. — Properties of Ferric Compounds. *Materials:* Ferric chloride solution and the solutions used in Experiment 157.

To a little ferric chloride solution add (1) sodium hydroxide solution. The precipitate is ferric hydroxide. Describe it. Add to ferric chloride solution (2) a little solution of potassium ferricyanide. Compare the negative result with (2) in Experiment 157. Add as above (3) a little solution of potassium thiocyanate. The rich wine-red coloration is caused by the soluble ferric thiocyanate. This test distinguishes ferric from ferrous compounds. Add as above (4) a little solution of potassium ferrocyanide. The precipitate is ferric ferrocyanide. Describe it. Tabulate the results of these two experiments, showing the behavior of ferrous and ferric compounds under the same conditions.

Experiment 159. — Reduction of Ferric Compounds. *Materials:* Ferric chloride solution, zinc, hydrochloric acid.

Put a piece of zinc in ferric chloride solution made slightly acid by hydrochloric acid. The nascent hydrogen reduces the ferric to ferrous chloride. After the operation has proceeded for about fifteen minutes, test a portion of the liquid for a ferrous and a ferric compound by Experiments 157 (2) and 158 (3). If the tests are not conclusive, continue the reduction and test again. Describe the result.

Experiment 160. — Oxidation of Ferrous Compounds. *Materials:* Ferrous sulphate, hydrochloric acid, potassium chlorate, nitric acid.

(*a*) To a solution of fresh or freshly washed ferrous sulphate add a little hydrochloric acid, warm gently, and then add a few crystals of potassium chlorate. After heating a short time, test portions of the liquid for a ferric and a ferrous compound.

(*b*) Add 10 cubic centimeters of concentrated nitric acid, drop by drop, to a hot solution of ferrous sulphate to which a little sulphuric acid has been added, and boil. Test portions of the liquid for a ferric and a ferrous compound as in Experiment 159.

(*c*) Recall a third illustration of the oxidation of a ferrous to a ferric compound. Describe it briefly.

Experiment 161. — Properties of Certain Iron Compounds. *Materials:* Ferrous sulphate, hematite, limonite, magnetite, pyrite, siderite.

(*a*) Examine a crystal of ferrous sulphate, and state its most obvious properties. Heat it gently in a test tube inclined mouth downward. Describe the result. Test this crystal for ferrous and ferric compounds as in Experiment 159. State and explain the result. What is the common name of ferrous sulphate?

(*b*) Examine hematite, limonite, and magnetite, and state their properties. Draw the first two across a rough sheet of paper or a piece of ground glass, and describe the "streak" made by each. What is the formula of each compound? Prepare a hydrochloric acid solution of each and test for iron. State the result.

(*c*) Examine pyrite, and state its properties. It is iron disulphide. What is its formula? For what is it used? For what is it sometimes mistaken?

(*d*) Examine siderite, and state its properties. It is ferrous carbonate. What is its formula? Test a powdered specimen for a carbonate and for iron. State the result.

Exercises for Review.

1. What happens when iron is (*a*) treated with acids, and (*b*) heated with sulphur?

2. Describe ferrous sulphide. What are formed by its interaction with warm hydrochloric acid?

3. What happens to iron when it is placed in copper sulphate solution?

NICKEL AND COBALT.

Experiment 162. — Test for Nickel.

To a solution of nickel chloride add sodium hydroxide to alkaline reaction. The precipitate is nickelous hydroxide. Describe it.

Experiment 163. — Test for Cobalt. Repeat Experiment 102 (*a*).

ORGANIC COMPOUNDS.

Experiment 164. — Composition of Organic Compounds. *Materials:* Turpentine, alcohol, camphor, kerosene, sugar, starch, flour, wood, paper, hair, candle, taper, gelatine, mustard, silver coin, red litmus paper, soda lime, porcelain dish, kerosene lamp, two bottles.

(*a*) *Carbon.* (1) Recall or repeat the experiments which showed that carbon is a constituent of wood, cotton, starch, sugar, illuminating gas and candle wax. (2) Heat a few drops of turpentine in a porcelain dish, and then set fire to it. Does it contain carbon? Hold a bottle over the flame long enough to collect any product, and then test the contents for carbon dioxide with limewater; does the observation verify the previous conclusion? (3) Repeat (2) with alcohol. Does alcohol contain carbon? (4) Burn a small lump of camphor in a porcelain dish or on a block of wood. Does it contain carbon? (5) Hold a bottle over a burning kerosene lamp long enough to collect any product, and test as in (2). Does kerosene contain carbon?

(*b*) *Hydrogen.* (1) Set fire to a few drops of the following liquids in a porcelain dish, and hold over each flame a *cold* dry bottle long enough to allow the condensation of the water vapor, which is always one product of the combustion of organic compounds which contain hydrogen: alcohol, turpentine, kerosene. (2) Heat in separate test tubes the following dry solids, and if they contain hydrogen, a little water vapor will condense on the upper part of the test tube: sugar, starch, flour, wood, paper, hair. (3) Hold a cold, dry bottle for a few seconds over a burning kerosene lamp, a Bunsen flame, an ordinary gas flame, a burning candle, a burning taper, and describe the result. Is hydrogen a component of kerosene, illuminating gas, and wax?

(*c*) *Oxygen*, which unites with the hydrogen of organic compounds to form the water, may come from the compound, as in the case of sugar, starch, wax, wood, paper, or it may come from the air. No simple experiment will determine the source of the oxygen.

(*d*) *Nitrogen.* Mix a little granulated gelatine (one part) with dry soda lime (two parts) and heat the mixture in a test tube. Hold a piece of moist red litmus paper in the escaping vapor. It will be turned blue by escaping ammonia gas. Gelatine (also horn, glue, and leather) contains nitrogen, which is liberated in combination with hydrogen as ammonia gas.

(*e*) *Sulphur.* (1) Put a little mustard paste on a clean silver coin. The brown stain is silver sulphide. Explain. (2) Why is a silver spoon tarnished by a cooked egg?

Draw a general conclusion regarding the composition of organic compounds.

Experiment 165. — Preparation and Properties of Alcohol. (Teacher's Experiment.) *Materials:* Grape sugar, yeast, limewater, bone black, sodium hydroxide. The *apparatus* consists of a large bottle provided with a one-hole rubber stopper fitted with a delivery tube (like *C*, *D*, *E*, in Fig. 104) which reaches to the bottom of a small bottle; the latter has a two-hole stopper. The delivery tube passes through one hole, and through the other passes a bent tube connected with a U-tube.

I. Put a liter of water in the bottle, add 150 grams of grape sugar, and shake until dissolved; pour 150 cubic centimeters of yeast into this solution. Fill the small bottle half full of limewater. Fill the U-tube with pieces of sodium hydroxide. Connect the apparatus and stand it in a dark place, where the temperature is 25°–30° C.

Fermentation begins at once, and carbon dioxide — one of the products — bubbles through the limewater, which is protected from the action of the air by the sodium hydroxide. Examine the stopper for a leak, if no change occurs in the limewater. The operation should be allowed to continue at least a day, and longer if possible. The flask will then contain mainly water, unchanged grape sugar, alcohol, and some products of minor importance. Pour off the liquid, agitate it with a little bone black to remove the odor and color, and filter. The alcohol, which varies in quantity with the conditions, is dissolved in a large excess of water and must be separated by distillation.

II. The distillation is performed with the apparatus used in Experiment 13. Fill the flask half full of the liquid from I, add a few pieces of pipestem (or granulated zinc, or glass tubing) to prevent "bumping," and distil about 50 cubic centimeters. Save the distillate. Replace the residue in the flask by more liquid from I, distil again, and repeat this operation until all the liquid has been used. Replace the one-hole stopper with a two-hole stopper, insert a thermometer in one hole so that the bulb just touches the surface of the combined distillates, which should now be distilled. Heat gently, and collect in a separate receiver the distillate which is formed when the liquid boils between 80° and 93° C. This distillate contains most of the alcohol.

Test as follows: —

(*a*) Note the odor.

(*b*) Drop a little into a warm dish, and hold a lighted match over it. If it does not burn, it shows that the alcohol is too dilute. Put a little in a dish, warm gently, and light the vapor. Describe the result.

Experiment 166. — Properties of Alcohol. (**Optional.**) *Materials:* Alcohol, camphor, shellac, rosin, porcelain dish.

(*a*) Determine cautiously the odor and taste of alcohol. Drop a little on a glass plate or on a piece of paper, and watch it evaporate. Is its rate of evaporation more rapid than that of water?

(*b*) Weigh a measured quantity (about 25 cubic centimeters) of 95 per cent alcohol and calculate its specific gravity.

(*c*) Alcohol dissolves many organic substances. Try camphor, powdered shellac, or rosin. Describe the result. Verify the solvent power of alcohol by adding water to the solutions. Describe the result.

(*d*) Burn a little alcohol in a dish and observe the nature of the flame. What are the products of combustion?

Experiment 167. — Preparation and Properties of Aldehydes. *Materials:* Concentrated hydrochloric acid, ethyl alcohol, potassium dichromate solution, methyl alcohol, copper wire, forceps.

(*a*) *Acetic Aldehyde.* Add a little concentrated hydrochloric acid and several drops of ethyl alcohol to several cubic centimeters of potassium dichromate solution. Warm gently, and observe the peculiar-smelling gaseous product. It is aldehyde vapor, aldehyde itself being a colorless, extremely volatile liquid, which boils at 20.8° C.

(*b*) *Formic Aldehyde* or *Formaldehyde.* Put a few cubic centimeters of methyl alcohol in a test tube and stand the test tube in a rack. Wind a piece of copper wire into a spiral around a glass rod or lead pencil. Slip the spiral from the rod, grasp one end into the forceps, and heat the wire red-hot in the flame. Then quickly drop it in the methyl alcohol. The pungent vapor which is suddenly produced is largely the vapor of formaldehyde.

Experiment 168. — Properties of Ether. *Materials:* Ether, evaporating dish, glass plate, wax.

Precaution. *Ether vapor is easily ignited, and should never be brought near a flame.*

(*a*) Pour a little ether into a dish or test tube and observe the odor and volatility. Taste cautiously. Pour a drop upon a glass plate or a block of wood. How does its rate of evaporation compare with that of alcohol? Pour a little upon the hand and describe the result.

(*b*) Add a bit of wax to a few cubic centimeters of ether, and shake. The result is typical; draw a conclusion.

Experiment 169. — Properties of Acetic Acid.

Treat acetic acid as follows: —

(*a*) Taste (cautiously), and describe.

(*b*) Test with litmus paper, and describe the result.

(*c*) Warm a little in a test tube, and smell (cautiously). Describe the odor.

Experiment 170. — Properties of Vinegar.

(*a*) Show, experimentally, that vinegar contains acetic acid.

(*b*) Repeat Experiment 60, using vinegar instead of indigo solution.

Experiment 171. — Test for Acetic Acid and Acetates.

Cautiously add a few drops of concentrated sulphuric acid to equal (and small) volumes of acetic acid and alcohol. Shake and warm gently. The pleasant, fruitlike odor is due to the vapor of ethyl acetate, a volatile liquid which is always formed under these circumstances. (NOTE. — This experiment is also a test for alcohol.)

Experiment 172. — Preparation and Properties of Acetates. *Materials for* (*a*) *:* Sodium carbonate, acetic acid, concentrated sulphuric acid, alcohol, porcelain (or agate) dish. *For* (*b*) *:* Litharge, acetic acid, porcelain dish.

Prepare one or both of the following acetates: —

(*a*) *Sodium acetate.* Dissolve 20 grams of sodium carbonate in 10 cubic centimeters of water in a porcelain (or agate) dish, and slowly add 30 cubic centimeters of commercial acetic acid, with constant stirring. If the solution is not acid, add a little more acetic acid. Filter the solution, if not clear. Evaporate to crystallization. When the crystals have formed, remove and dry them. Describe the crystals. Prove that they contain water of crystallization. Test the acetate as follows: (1) Dissolve a little in water, add a few drops of concentrated sulphuric acid, and boil. What does the odor show is present? What other acids have been similarly prepared? (2) Dissolve as in (1), add a few drops of alcohol and of sulphuric acid, and boil. What does the odor conclusively prove? Preserve the crystals, finally, in a glass-stoppered bottle, or in one having a cork covered with paraffin.

(*b*) *Lead acetate* (*poisonous*). To 10 grams of litharge add 18 cubic centimeters of commercial acetic acid in small portions. Stir the mixture constantly during the addition of acid. After all the acid has been added, heat gently until the action ceases. (If the solution is green or bluish, it is due to a copper compound. The copper may be precipitated and removed mechanically by standing a strip of lead in the solution for an hour or more. Pour off the clearer liquid and then filter.)

Evaporate cautiously to crystallization. Remove the crystals from the liquid, and dry at a moderate temperature. Preserve the crystals finally as in (*a*). Describe the crystals. Test them for lead (see Exp. 145 (*b*)), and for an acetate.

Experiment 173. — Properties of Certain Organic Acids. *Materials:* Tartaric and citric acids, potassium permanganate solution, sodium bicarbonate, sugar, concentrated nitric acid, evaporating dish, litmus paper.

(1) *Tartaric acid.* Observe and describe the results in the following: (*a*) Taste cautiously a dilute solution of tartaric acid. (*b*) Apply the litmus test. (*c*) Add a little of the solution to a sodium bicarbonate solution. (*d*) Dissolve two or three crystals of potassium permanganate in a test tube half full of water, add a little sodium hydroxide solution and two or three pieces of tartaric acid (solid). Warm gently, but do not shake. The change is due to the reduction of the potassium permanganate by the tartaric acid.

(2) *Citric acid.* Proceed as in (1) with citric acid.

(3) *Oxalic Acid.* (*a*) **This acid is poisonous. Do not taste it.** (*b*) and (*c*) Proceed as in (1). (*d*) Dissolve two or three crystals of potassium permanganate in a test tube half full of water and add half the volume of sulphuric acid. Add oxalic acid solution until a decided change appears. Describe and explain it. (*e*) Add a few drops of ink to oxalic acid solution, and shake. Describe the result.

Experiment 174. — Preparation and Properties of Ethyl Acetate.

Repeat Experiment 171.

ANSWER:

(1) What class of organic compounds does ethyl acetate represent? What general property has this class?

(2) To what inorganic compound does ethyl acetate correspond?

(3) What is the relation of ethyl acetate to (*a*) alcohol and (*b*) acetic acid?

Experiment 175. — Preparation of Soap.

Prepare soap in an iron or a tin dish by one of the following methods: —

(*a*) Dissolve 10 grams of sodium hydroxide in 75 cubic centimeters of water, add 30 grams of lard, and boil until the mixture begins to solidify. Then add 20 grams of fine salt in small portions. Stir constantly during the addition of the salt. Boil a few minutes. Let the mass cool, and then remove the soap, which will form in a cake at the surface.

(*b*) Dissolve 13 to 15 grams of sodium hydroxide in 100 cubic centimeters of water, add 100 cubic centimeters of castor oil, and boil for about half an hour. Add 20 grams of salt, and then proceed as in (*a*).

(*c*) Dissolve 8 grams of potassium hydroxide in 150 cubic centimeters of alcohol, add 10 grams of lard, and stir constantly while the mixture is being heated cautiously to sirupy consistency. Allow the solution to cool. The jellylike product is soap.

Preserve a sample.

Experiment 176. — Properties of Soap. *Materials:* Soap, sulphuric acid, calcium sulphate, magnesium sulphate, and acid calcium carbonate solutions.

Test as follows the soap prepared in Experiment 175: —

(*a*) Leave soap shavings exposed to the air for several days. What does the result show about the presence of water in the soap?

(*b*) Test soap solution with litmus paper.

(*c*) Add considerable dilute sulphuric acid to a soap solution. The precipitate is a mixture mainly of palmitic and stearic acids. Describe it.

(*d*) To a little soap solution in separate test tubes add calcium sulphate and magnesium sulphate solutions. Describe the result. Boil for a few minutes and describe the result. Prepare a solution of acid calcium carbonate by passing carbon dioxide into limewater until the precipitate is redissolved (see Exp. 69). Add some of the solution to a soap solution, and describe the result. Boil, as above, and describe the result.

ANSWER:

(1) What is hard water? Soft water?

(2) What is permanent hardness? Temporary hardness? How can the later be removed?

Experiment 177. — Properties of Glycerine.

(*a*) Add a little glycerine to a test tube half full of water, and shake. Add considerable more glycerine, and shake. What does the result show about the solubility of glycerine in water?

(*b*) *Cautiously* taste the liquid resulting from (*a*). Describe the result.

Experiment 178. — Fehling's Test for Sugar. *Materials:* Copper sulphate, Rochelle salt, sodium hydroxide, and grape sugar solutions.

Mix equal (and small) volumes of copper sulphate, Rochelle salt, and sodium hydroxide solutions in a test tube, and boil carefully. The mixture should be strongly alkaline. Add a little grape sugar solution, and boil until a decided change is produced. The precipitate is cuprous oxide. Describe it.

(NOTE. — Cane sugar must be changed to grape sugar by boiling with dilute sulphuric acid before the above test is applicable.)

Exercises for Review.

1. What happens to sugar and starch (*a*) when heated, and (*b*) when treated with concentrated sulphuric acid?
2. What is the test for starch?
3. Discuss the solubility of alcohol in water.
4. What is the effect of heat upon paper and cotton? Of potassium permanganate on paper?

Experiment 179. — Properties of Benzene.

Put *one or two drops* of benzene in an evaporating dish, and **cautiously** bring a lighted match near it. Describe the result.

LABORATORY EQUIPMENT.

The Equipment of a laboratory should be limited solely by the means at the disposal of the teacher. Accurate and rapid work is largely determined by the available facilities, and no pains should be spared to secure the equipment which will yield the largest educational return for the time and money expended.

The lists given below include the apparatus and chemicals needed for the experiments in this book. Quantities and prices have been omitted in justice to teachers, dealers, and the author. Different teachers use different quantities, prices fluctuate, and qualities vary. The author, at his own suggestion, has lodged with the L. E. Knott Apparatus Co., 16 Ashburton Place, Boston, Mass., information regarding the quantities of apparatus and chemicals used by his classes. It is hoped that teachers will correspond with both author and dealer when preparing order lists. The author takes this opportunity to say that he has no financial connection whatever with any dealer in scientific supplies.

LIST A. — INDIVIDUAL APPARATUS.

This list includes the apparatus constantly used by a single student, who should be provided with each piece. The set will cost from $4.75 to $5. The discount on apparatus in this and succeeding lists depends upon the total amount of the order.

6 Test tubes, 6 × $\frac{3}{4}$.
3 Test tubes, 8 × 1.
1 Test-tube holder.
1 Test-tube rack.
1 Test-tube brush.
1 Bunsen burner.
1 Blowpipe.
1 Blowpipe tube.
5 Bottles, wide mouth, 250 cc.
1 Funnel, $2\frac{1}{2}$ in.
1 Evaporating dish.
1 Pair iron forceps.
1 Triangular file.
1 Mortar and pestle, 3 in.
1 Deflagrating spoon.
1 Pneumatic trough.
2 ft. Rubber tubing, $\frac{1}{4}$ in. in diam.
100 Filter papers, 4 in.
1 ft. Glass rod.
6 in. Rubber tubing, $\frac{3}{16}$.
1 One-hole and 1 two-hole rubber stopper to fit large test tube.
4 ft. Glass tubing to fit rubber stoppers (above).
1 Safety tube.

LIST B. — SPECIAL APPARATUS.

This list includes apparatus used occasionally. Numbers in parentheses refer to experiments. The set will cost from $3 to $3.25.

1 Crucible, Hessian, 4 in. deep (59, 90).
1 Dish, lead (80).
1 Flask, Erlenmeyer, 250 cc. (25).
1 Pinchcock, Mohr (96).
1 Screw, Hofmann (25).
1 Thistle tube (96).
1 Lamp chimney (77).
1 Graduated cylinder, 25 cc. (25 and others).
1 Magnet (156).
1 Candle (63, 77).
1 Sand-bath pan, 4 in.
1 Wing-top burner (Int. § 3(*b*)).
1 Dish, iron or tin (109, 111).
1 Retort, 250 cc. (49).

LIST C. — APPARATUS FOR TEACHER'S EXPERIMENTS.

This list includes the additional apparatus for the Teacher's Experiments. Numbers in parentheses refer to experiments. The set will cost about $11.

Electrolysis apparatus (22, 36).
Flask, 500 c.c. (10, 13, 165).
Two-hole rubber stopper for above.
U-tube (10, 73, 165).
2 One-hole rubber stoppers for above.
4 in. Capillary tubing (10, 22, 36).
3 ft. Glass tubing to fit rubber stoppers.
1 Safety tube (10).
1 Condenser complete (13, 165).
1 Tripod (13).
1 Thermometer (165).
1 Chlorine tube (23).
1 Ignition tube, 6 in. (73).
1 Bottle, wide mouth, 50 cc. (10).
Battery, 3 cells (Grenet) (22, 36, 37).
1 Bottle, 2000 cc. (165).

LIST D. — GENERAL APPARATUS.

This list includes the general laboratory apparatus. It should be extended as demands arise. It does not include such items as duplicate stoppers, extra glassware, tools, etc. Special inexpensive articles are noted in the experiments and in the "Handbook for Teachers" accompanying this book.

Corks, assorted.
Copper wire, No. 24.
Glass plates, 4 × 4 in.
Iron stands, 3 rings, 2 clamps.
Matches.
Wire gauze, iron, 4 × 4 in.
Wooden blocks, 6 × 6 × 1 in., 6 × 6 × ¾ in., 4 × 4 × ½ in. (with ½ in. hole in center — see Exp. 38).
Sand.
Wood, thin sticks (Exp. 6 and others).
Rule, foot and 30 cm.
Scales, trip.
Weights for above.
Tapers.
Emery paper.
Kerosene lamp.
Graduated cylinders, 500 cc., 100 cc.

LIST E. — CHEMICALS.

This list includes the chemicals needed for this book. Numbers in parentheses refer to experiments in which the chemicals are used.

Acid, acetic.
citric.
Acid, hydrochloric.
nitric.

Acid, oxalic.
    pyrogallic (25).
    sulphuric.
    tartaric.
Alcohol, ethyl.
    methyl (167).
Alum, chrome.
    potassium.
Aluminium, metal.
    sulphate.
Ammonium, chloride.
    hydroxide.
    nitrate.
    oxalate.
    sulphide.
Arsenious oxide (95, 105).
Asbestos, shredded (73).
Baking powder (68).
Barium chloride.
    nitrate (125).
Benzene (179).
Bismuth (107).
Bleaching powder.
Borax (powd.).
Cadmium chloride (131).
Calcium carbide (72).
    carbonate (marble).
    chloride.
    fluoride (80).
    oxide (lime).
    sulphate.
Carbon disulphide.
Chalk (native) (68).
Charcoal, animal (powd.).
    lump.
    wood (powd.).
Coal, soft.
Cobalt nitrate.
Cochineal.
Coin (silver).
Copper nitrate.
    sheet.
    sulphate (cryst.).
Cotton (absorbent).
Cream of tartar.
Ether.
Galena (148).
Gelatine.
Glycerine.
Gold leaf (book).
Hematite (161).
Indigo.
Iodine.
Iron, chloride (*ic*).
    filings.
    powder.
    pyrites (161).
    sulphate (*ous*).
    sulphide (*ous*).
    wire (fine).
    wrought.
Kerosene.
Lead acetate.
    carbonate.
    dioxide (peroxide).
    nitrate.
    monoxide (litharge).
    sheet.
    tea.
    tetroxide.
Limonite (161).
Litmus paper.
Magnesium oxide.
    ribbon.
    sulphate.
Magnetite (161).
Manganese dioxide.
    sulphate.

Mercury.
Mercuric chloride.
    nitrate.
    oxide (7).
Mercurous nitrate.
Mustard.
Nickel chloride (162).
Paraffin.
Phenolphthalein (66).
Picture cord (iron) (6).
Potassium, metal (110).
    bromide.
    carbonate.
    chlorate (cryst.).
    chlorate (powd.).
    chloride.
    chromate.
    dichromate.
    ferricyanide.
    ferrocyanide.
    hydroxide.
    iodide.
    nitrate.
    permanganate.
    sulphate.
    sulphocyanide (thiocyanate) (157–158).
Pyrite (161).
Rochelle salt (178).
Rosin.
Selenite (gypsum, cryst.).
Shellac.
Siderite (161).
Silver nitrate.
Soap.
Soda lime (164).
Sodium, metal.
    bicarbonate.
    carbonate.
    chloride.
    hydroxide.
    hyposulphite (thiosulphate).
    nitrate.
    phosphate (disodium phosphate).
    silicate (101).
    sulphate.
    sulphite (96).
Stannous chloride (tin crystals).
Starch.
Steel.
Strontium nitrate (123).
Sugar, cane.
    grape (165).
Sulphur, flowers.
    roll.
Tartar emetic.
Tin, granulated.
Tooth powder (68).
Turpentine.
Vaseline.
Vinegar.
Water, distilled.
Whiting (68).
Wood ashes.
Zinc, granulated.
    oxide.
    sheet.
    sulphate.

SOLUTIONS.

The following solutions are needed for the experiments in this book. Those not included are described in the experiments requiring their use.

Alum, 10 per cent.
Ammonium chloride, 10 per cent.
Ammonium hydroxide, 1 vol. to 3 vols. water.
Ammonium oxalate,[1] 4 per cent.
Ammonium sulphide, 1 vol. to 1 vol. water.
Barium chloride,[2] 5 per cent.
Battery solution (Grenet). Dissolve 103 gm. powdered potassium dichromate in 1 liter of water and slowly add 103 gm. conc. sulphuric acid with constant stirring.
Calcium chloride, 10 per cent.
Chlorine water,[1] saturated (see Exp. 23, 38).
Cobalt nitrate, 5 per cent.
Cochineal. Prepare as described under Indigo.
Copper sulphate, 10 per cent.
Disodium phosphate, 10 per cent.
Ferric chloride, 5 per cent.
Ferrous sulphate,[1] 10 per cent.
Hydrochloric acid, 1 vol. to 4 vols.
Indigo. Grind a little with water and dilute as desired.
Iodine. Grind to solution 12 gm. iodine, 20 gm. potassium iodide, 10 cc. water, and add to 1000 cc. water.
Lead acetate, 10 per cent.
Lead nitrate, 10 per cent.
Limewater. Let water stand over lime for several days, and siphon off the clear liquid.
Magnesium sulphate, 10 per cent.
Manganese chloride, 10 per cent.
Mercuric chloride, 5 per cent. **Poison.**
Mercurous nitrate,[3] 5 per cent.
Nitric acid, 1 vol. to 4 vols. water.
Potassium bromide, 5 per cent.
Potassium chloride, 5 per cent.
Potassium chromate, 10 per cent.
Potassium dichromate (or bichromate), 5 per cent.
Potassium ferricyanide, 10 per cent.
Potassium ferrocyanide, 10 per cent.
Potassium hydroxide, 10 per cent.
Potassium iodide, 5 per cent.
Potassium nitrate, 10 per cent.
Potassium permanganate,[2] 5 per cent.
Potassium sulphate, 10 per cent.
Potassium thiocyanate (or sulphocyanide), 1 per cent.
Silver nitrate, 5 per cent.
Sodium carbonate, 10 per cent.
Sodium chloride, 10 per cent.
Sodium hydroxide, 10 per cent.
Stannous chloride.[1] Dissolve 500 gm. of the salt in 1000 cc. hot conc. hydrochloric acid, and add a piece of tin.
Sulphuric acid, 1 vol. to 4 vols. water.
Tartar emetic, 10 per cent.
Zinc sulphate, 10 per cent.

---

[1] Must be freshly prepared.

[2] Use distilled water.

[3] Use distilled water, and add 75 cc. concentrated nitric acid and a little mercury.

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